HALCON Version 6.1.4

Getting Started with HALCON

User's Manual

Getting Started with HALCON, Version 6.1.4

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About This Manual

This manual is a quick guide to HALCON – the software solution for machine vision applications. HALCON is a sophisticated image analysis package suitable for product development, research, and education. It provides operators covering a wide range of applications: Factory automation, quality control, remote sensing and aerial image interpretation, medical image analysis, and surveillance tasks. For rapid prototyping, HALCON includes HDevelop, a highly interactive programming environment which allows to design and test image analysis programs and to generate C, C++, or COM code.

The manual provides all necessary information to install and configure HALCON, to understand its basic philosophy, and to get acquainted with HDevelop.

The manual is intended for all new users of HALCON. It does not assume that you are an expert in image processing. Regardless of your skills, it is quite easy to work with HALCON using HDevelop. Anybody should be able to understand the basic HALCON principles to solve his image analysis problems quickly. Nevertheless, it is helpful to have an idea about the functionality of *graphical user interfaces (GUI)*,[1] and about some basic image processing aspects.

The manual is divided into the following chapters:

- **Introducing HALCON**
  This chapter provides a short overview of the HALCON system and points out additional sources of information about HALCON.
- **Installation, Licensing, Configuration**
  This chapter explains how to install and configure HALCON. Furthermore, it describes the different types of licenses and how to obtain them.
- **A First Look at HDevelop**
  This chapter contains a complete HDevelop session showing how to solve a specific image analysis task from the scratch.
- **Philosophy of HALCON**
  This chapter explains the basic data structures and mechanisms of HALCON.
- **Using Parallel HALCON**
  This chapter shows how to use Parallel HALCON.
- **Tips and Tricks**
  This chapter contains helpful information, e.g., for troubleshooting.

[1] Consult your platform's documentation for general information.

Release Notes

Please note the latest updates of this manual:

- **Edition 6c, HALCON 6.1.3 (April 2004)**
  The manual now warns that after updating to a maintenance release that uses a newer version of the FLEXlm license manager software, you must restart the license manager daemon.

- **Edition 6b, HALCON 6.1.2 (May 2003)**
  The manual now uses the terms “license / license file / license key” and “update / upgrade” consistently. Furthermore, it warns that the number of modules should be determined in the actually used environment and describes how to customize the port number of the floating license daemon.

- **Edition 6a, HALCON 6.1.1 (December 2002)**
  The manual has been clarified and extended at many points. For example, it now clearly states that an application can only use one HALCON language interface, that the license file MUST be called license.dat and describes how to upgrade a license. DOS shells are now called Windows Command Prompts. Furthermore, the section regarding floating licenses has been extended and the troubleshooting for problems during uninstallation now differentiates between HALCON 6.0 and 6.1. Finally, the manual reflects the support of gcc-3.2.

- **Edition 6, HALCON 6.1 (June 2002)**
  The problems occurring in conjunction with the new version of the dongle driver required for HALCON 6.0.2 and their solution are described in the corresponding sections. Furthermore, the installation process is now described in more detail, including information on how to switch between different HALCON versions. A new section contains additional information for users of ActivVisionTools.

- **Edition 5b, HALCON 6.0.2 (February 2002)**
  The manual now contains more details regarding the use of dongles (parallel port and USB) including how to install, configure, and uninstall the corresponding device drivers.

- **Edition 5a, HALCON 6.0.1 (July 2001)**
  The manual now contains more information about how to install HALCON and the license file when using floating licenses and about the customization of the port number of the license server daemon. Furthermore, the section ’Troubleshooting’ now offers help if licensing via a network board fails under Windows 2000.

  Since HALCON 6.0.1 does not support HP-UX anymore, the corresponding sections have been deleted from the manual.

- **Edition 5, HALCON 6.0 (October 2000)**
  The manual has been completely revised regarding structure and content, with exception of the HDevelop example session. An additional chapter concerning Parallel HALCON has been introduced. The information about installing, licensing, and configuring HALCON has been extended and moved to an own chapter. The chapter ”Philosophy” has been extended by a section describing the HALCON frame grabber interface.

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Chapter 1

Introducing HALCON

Congratulations! With HALCON you have chosen a sophisticated image analysis package designed for product development, research, and education. HALCON provides a unique library with about 1000 operators covering a wide range of image analysis tasks, data visualization, and a comfortable debugging mechanism. HALCON operators can be used within C and C++ programs on Windows NT/2000/XP and many UNIX platforms. In addition, under Windows NT/2000/XP , HALCON has a COM interface. This allows you to use HALCON operators from Visual Basic, for example. Furthermore, it is very easy to integrate your own specific operators into the system.

The HALCON data structures for iconic data provide a very convenient handling of images, regions, and contours. Optimized algorithms allow high performance even on standard hardware.

The HALCON system also includes the programming environment HDevelop which allows to speed up the design of image analysis programs. A smart online help based on an *operator knowledge base* provides information about each HALCON operator, e.g., reasonable successors, possible alternatives, cross references, etc.

From version 6.0 on, HALCON exists in two versions: Besides "standard" HALCON you can now choose Parallel HALCON. In addition to HALCON's image processing functionality, Parallel HALCON automatically exploits multi-processor hardware and supports parallel programming. See section 1.3 for more information on Parallel HALCON.

Let's start with some facts describing the main characteristics of both HALCON versions.

1.1 Facts about HALCON

- **HALCON's comprehensive operator library supports efficient, flexible image processing and eases the development of image analysis programs**.

  HALCON's operator library contains *about 1000 operators*. The operators can be used in any combination. All HALCON applications (e.g., HDevelop or HALCON/C++ programs) make use of the library to perform image processing tasks.

  The operators exhibit a *broad range of functionality*, from simple tasks (e.g., "read image from file") to complex processes (e.g., "estimate state by Kalman filtering"). Basically they all have a rather lean complexity and are meant to process single steps of a task instead of the whole task. So, the typical solution of an image analysis problem consists

of a combination of several HALCON operators. This concept allows much greater flexibility than others based on fewer, but more complex operators that are specialized to perform a certain task. Specialized operators are only suitable for special tasks and become worthless when the task changes. In contrast to this, HALCON operators may be used in any combination.

Among the great number of operators there are some that implement the same task by different algorithms. This allows to vary how fast and precisely a task is performed. Consider pattern matching, for example: For a task where only the rough positions of matching points are needed, but where the results must be returned as fast as possible, the operator `fast_match` may be used. In contrast to this, `best_match` is the better choice when needing the exact positions (even with subpixel accuracy) by using a more time-consuming algorithm.

- **HALCON processes color and multi-channel images**.

  HALCON works on all kinds of image data — binary, monochrome, color, or multi-channel images. You may use all these kinds of images in the same manner. Multi-channel images are useful to work on images that were acquired by a multisensor system.

- **HALCON implements efficient, fast region processing**.

  This speeds up the processing and eases the handling of regions. Regions may overlap and can be of any size. They are stored by an optimized encoding to reduce memory costs.

- **HALCON allows to focus image processing on a region of interest**.

  Each image object has a domain — its area of definition — that can be changed by the user. When performing an image operator, it is processed only within the domain of the input image. This concept allows to focus image processing on regions of interest (ROIs) and therefore to speed it up.

- **HALCON provides very fast pattern matching operators**.

  Pattern matching is very helpful in numerous areas of application, but often not used due to its costs of computation time. HALCON allows to use pattern matching where you want to, as it uses a very efficient implementation of various pattern matching algorithms.

- **HALCON provides shape-based matching operators that work even in the presence of occlusion or clutter**.

  HALCON provides not only pattern matching but also *shape-based matching* operators. With these operators, you can recognize objects even if they are scaled, partly occluded or in the presence of clutter or changing illumination conditions. From version 6.1 on, HALCON provides the auxiliary tool *HMatchIt* , which lets you configure and test the matching process with a few mouse clicks; besides, this tool helps you to optimize the parameters interactively to get the maximum matching speed and recognition rate.

- **HALCON provides an easy handling of tuple objects and processes tuple elements simultaneously**.

  Tuples are very helpful in many areas of application, since they enable you to work with sets of images, regions, or control data. With HALCON, tuples of objects or control values can be handled just as one object. Operators can either work on a single or on a tuple object. You need not bother about the amount of elements within a tuple. You simply pass one variable containing the tuple to an operator. HALCON decomposes it

and works simultaneously on the tuple elements.

- **HALCON is based on an efficient management of image and data objects**.

  The HALCON memory management uses fast, efficient algorithms to speed up image processing. It provides mechanisms for controlled memory access and services for debugging, such as checking with every deallocation whether any write access exceeded the allocated memory block. The HALCON image database provides several services for object handling to allow a fast and transparent access to image data. Images are held in memory. To reduce memory costs data is shared by different objects whenever possible.

- **HALCON provides interfaces to the programming languages C, C++, and COM**.

  The HALCON system includes interfaces to the programming languages C, C++ , and COM[1]. This allows you to use HALCON operators inside your own C, C++, or COM programs and to build stand-alone applications.

- **HALCON provides the tool HDevelop for interactive development of image analysis programs**.

  In most cases, developing image analysis programs is a complex and time-consuming task. To help the user to find the right operators and parameters for a given task, HALCON provides the *Computer Aided Vision Engineering tool* HDevelop . This eases developing programs in several ways: First, HDevelop has a *graphical user interface* that allows an easy, intuitive handling of operators and image data. Secondly, operators can be processed and combined interactively. All results are immediately visualized so that the user can experiment with different operators and parameter values and directly sees the result. Moreover, HDevelop supports the user by suggesting appropriate operators and parameter values. An *online help* explains how the operators work and illustrates their usage by examples.

  If you are satisfied with the result you can save the developed program either in a special HDevelop file format to load it again into HDevelop later on or export the program as C, C++ , or COM source code. By exporting, the program can be used by other image analysis applications and can be edited and optimized just like any “hand-written” image processing program.

- **HALCON already provides interfaces to more than 50 frame grabbers**.

  HALCON supports more than 50 frame grabbers (the current list can be found at `http://www.mvtec.com/halcon/`) by providing interfaces to their SDKs. To establish a connection to one of these frame grabbers, all you need to do is to call the operator `open_framegrabber` with parameters describing the desired image format and grabbing mode. Then, you can grab images simply by calling the operator `grab_image`.

- **New frame grabbers may easily be integrated**.

  If you use a frame grabber not already supported by HALCON, you can easily integrate a corresponding interface into HALCON. For this, HALCON provides a transparent frame grabber interface with sample source code for integrating new frame grabbers. The only thing you have to do is to adapt this code to a specific frame grabber and to link it to the HALCON code. The Frame Grabber Integration Programmer’s Manual describes in detail how to do this.

[1] COM is a Microsoft standard for component-based software; programs written in COM can be used in environments such as Visual Basic , Visual C++ , Microsoft .NET , or Delphi.

Alternatively, you can convert your own images to HALCON images by passing HALCON a pointer to the image buffer using the operator gen_image1_extern.

- **HALCON may easily be extended by new operators**.

  Although HALCON already contains about 1000 operators for various tasks, you may wish to implement a new one, e.g., in order to access a special hardware or to implement an alternative algorithm. To do so, HALCON provides the Extension Package Interface that allows the integration of new operators (implemented in C) in form of so-called *extension packages*. It contains several predefined routines and macros for the easy handling of image data and memory objects in C. Once a new operator has been successfully integrated, it can be used like any other HALCON operator. The Extension Package Programmer's Manual contains detailed information about extending the operator library.

- **HALCON allows continued application of already implemented image processing software**.

  Software engineering is a time consuming process and in most cases expensive as well. So, everyone is interested in using already implemented software as long as possible, and no one is bent on re-implementing their software with every installation of new software components. Therefore, HALCON supports the continued application of already implemented software: Convert your programs into new HALCON operators to use them within HALCON as described above. Moreover, HALCON hardly restricts the hardware configuration. A wide range of machines and systems can be used. Various frame grabbers are supported. New ones may be easily integrated (see below). Thus, you need not change your hardware configuration and therefore also need not to change your software.

- **HALCON supports a wide range of platforms**.

  HALCON is largely architecture independent and therefore allows you to use the system of your choice. It supports different operating systems, such as Windows NT/2000/XP , Linux , Solaris , Tru64 UNIX (formerly called DIGITAL UNIX), or IRIX . See section 1.2 for more information.

- **HALCON supports multi-threaded applications by being thread-safe**.

  HALCON is thread-safe under Windows NT/2000/XP, Linux, and Solaris. Note, that for an extensive use of parallel programming techniques, you should choose Parallel HALCON (see section 1.3).

- **HALCON supports data exchange with other applications**.

  For easy exchange of image data HALCON supports several file formats, such as Tiff, Sun-Raster, Gif, PNM, PNG, JPEG, PCX, XWD, BMP, binary. Other data (e.g., integer result values for image coordinates) may be exchanged via the HALCON language interfaces.

1.2 System Requirements

Table 1.1 shows the requirements for running HALCON 6.0 on the different supported operating systems. It should run on newer versions of an operating system; however, we cannot guarantee this. Windows NT is no longer supported on Alpha processors, following Microsoft's corresponding decision.

Operating System	Processor	Compiler
Windows NT 4.0 / 2000 / XP	compatible to Intel Pentium	MS Visual Studio
Linux 2.2/2.4	compatible to Intel Pentium	`gcc 2.95`, `gcc 3.2/3.3`
Solaris 7	SPARC	`CC`
IRIX 6.5	MIPS	`CC`
Tru64 UNIX 5.1	Alpha	`cxx`

Table 1.1: Platforms supported by HALCON .

Note, that under Linux `libc6` (`glibc-2.1.x`) is required, which is the case for most current Linux distributions like RedHat or SuSE. Please check your distribution's documentation.

HALCON can also be used on the Philips TriMedia DSP, with the host computer running Windows NT/2000/XP. Please refer to the HALCON/C User's Manual for more infomation.

1.3 Introducing Parallel HALCON

To put it in a nutshell, standard HALCON is optimized for running *sequential programs* on *single-processor boards*. Under Windows NT/2000/XP , Linux , and Solaris , HALCON is *thread-safe*, i.e., it can be used in multi-threaded programs. However, all HALCON operators are executed *exclusively*, thus threads will have to wait for each other.

In contrast, Parallel HALCON supports *parallel programming* (e.g., multi-threaded programs) by being thread-safe *and reentrant*. This means that multiple threads can call a HALCON operator simultaneously[2]. Parallel HALCON is available for Windows NT/2000/XP , Linux , and Solaris .

Besides supporting parallel programming, Parallel HALCON *automatically parallelizes operators* if started on multi-processor hardware, e.g., a dual-pentium board. This mechanism is fully compatible to older HALCON versions, i.e., old HDevelop, C++, or C programs do not need to be changed.

The parallelization mechanism is based on distributing the data which has to be processed, i.e., the images, on multiple threads that run on different processors (so-called *data parallelism*). For example, for a filtering operation on a four-processor board the image will be split into four parts which will then be processed in parallel by four threads executing the (same) filtering operator. Together with HALCON's philosophy for treating images and regions, this form of parallelization is very efficient because images need not to be copied.

[2]Note, that some operators can only be called exclusively because of functional or technical reasons. See section 5.2.1 for more information.

The degree of parallelization is optimized online to minimize the parallelization overhead. For example, very small images will not be processed in parallel, as the overhead would surpass the parallelization speed-up. Moreover, not all HALCON operators lend themselves to parallelization.

To be able to exploit your multi-processor hardware optimally, Parallel HALCON has to check the hardware once after being installed. Section 5.1.1 describes how to start and configure this initialization.

Note, that Parallel HALCON is designed for *shared-memory systems*, i.e., systems in which multiple processors share a common memory as it is the case for typical multi-processor boards. The main reason is that only in a shared-memory system threads can share the HALCON object database and do not need to copy images. This limitation means that Parallel HALCON is not suited to the use on workstation clusters or other multi-processor hardware that does not offer shared memory.

1.4 Additional Sources of Information

For further information you may consult the following manuals:

- HDevelop User's Manual
  An introduction to the graphical development environment of the HALCON system.
- HALCON/C++ User's Manual
  How to use the HALCON library in your C++ programs.
- HALCON/C User's Manual
  How to use the HALCON library in your C programs.
- HALCON/COM User's Manual
  How to use the HALCON library in your COM programs, e.g., in Visual Basic.
- Extension Package Programmer's Manual
  How to extend the HALCON system with your own operators.
- Frame Grabber Integration Programmer's Manual
  A guide on how to integrate a new frame grabber in the HALCON system.
- HALCON/HDevelop , HALCON/C++ , HALCON/C , HALCON/COM
  The reference manuals for all HALCON operators (versions for HDevelop, C++, C, and COM).
- **Application Guide**
  Multiple, independent documents called Application Notes, written from the point of view of developing machine vision applications with HALCON. Each Note covers a specific topic, e.g., how to use shape-based matching to find and localize objects.

All these manuals are available as PDF documents. The reference manuals are available as HTML documents as well. For the latest version of the manuals please check

```
http://www.mvtec.com/halcon/
```

Chapter 2

Installation, Licensing, Configuration

Before describing how to install and configure HALCON, let's take a look at the different HALCON versions and licensing schemes.

You can obtain HALCON in three versions:

1. The *demo version* is basically a version of HDevelop with the full image processing functionality but some limitations, e.g., without frame grabber or programming language interfaces. Using the demo version, you can test all HALCON operators within the HDevelop environment for an unlimited amount of time.

2. At the other end of the spectrum lies the *full version*, which is used to develop applications based on HALCON. Besides HDevelop, this version includes interfaces to about 50 frame grabbers and an interface to integrate additional ones, language interfaces to C, C++, and COM, and the Extension Package Interface, which allows you to integrate your own HALCON operators.

3. If you have developed an application based on HALCON, you can obtain a *runtime version* of HALCON, which only contains the image processing functionality needed in your application. A runtime version does not include HDevelop.

For the development version and for the runtime version you need a corresponding license. *The demo version can be used without a license*. There are two possible licensing schemes:

1. *Nodelocked licenses* are only valid for one specific host or hardware dongle.

2. For a development version you can also get a so-called *floating license*. Such licenses are valid on arbitrary hosts within a local network. A so-called *license server* checks the number of currently active HALCON applications. A new application can be started only if the overall number of licenses is not exceeded.

   Note, that a computer acting as the HALCON license server need not be a "server" in the sense that it must be a "big" server machine or have a special kind of operating system, e.g., Windows NT Server, installed. Moreover, you can use different architectures for the license server and the HALCON applications, respectively, e.g., a Linux workstation for the license server and Windows for running HALCON. The only requirement is that the computer acting as the license server must be accessible whenever HALCON is to be used.

Please note, that for evaluating purposes you can obtain a temporary *evaluation license* from you distributor free of charge.

2.1 Installation

This section describes how to install HALCON from CD; how to install HALCON from the WWW is described in MVTec's download area (`http://www.mvtec.com/halcon/download`). Most of the work is done by the provided installation scripts. The file `release_notes.html` within the HALCON package contains the latest information.

Except of UNIX-specific sections, file paths and environment variables are printed in the Windows convention, e.g.,

```
%HALCONROOT%\examples\extension_package\halconuser
```

to denote the subdirectory `halconuser` containing an example package within the HALCON base directory referenced by the environment variable `HALCONROOT` (see section 2.4 for more information on environment variables). The same expression in UNIX convention would look like

```
$HALCONROOT/examples/extension_package/halconuser
```

Prior to installing a new HALCON version, e.g., HALCON 6.1.x over HALCON 6.0.x, you should uninstall any existing old version. Under Windows, this is especially important in order to clean up the registry. See section 2.2 about how to uninstall HALCON. An exception to this rule is if you are using ActivVisionTools 1.0 to 1.3 and want to install HALCON 6.1.x: In this case you must keep your old HALCON 6.0.x installation.

If you want to install a new maintenance release over an existing release based on the same version, e.g., HALCON 6.1.1 over HALCON 6.1, you can use a special update mechanism (see section 2.1.3).

2.1.1 Installing HALCON Under Windows NT/2000/XP

To install HALCON on Windows NT/2000/XP systems, simply insert the CD. This should automatically start the setup program. If the setup program doesn't start automatically, execute the `Setup.exe` program located in the directory `nt-x86` of the CD. Please note, that you need administrator privileges in order to install HALCON.

First, the setup program checks whether your system meets the requirements for running HALCON (see section 1.2).

Then, it checks whether HALCON is already installed on your computer and, if yes, which release is installed:

- **same release:** If you already installed the same release, the setup determines the installed components and lets you install additional parts.
- **same version:** If you already installed another release of the same version, e.g., if the setup of HALCON 6.1.1 detects HALCON 6.1, the setup enables you to replace the installed components by those of the new release. If you are using floating licenses, please note the following: After installing HALCON 6.1.2 on the computer acting as the

license server, you must **restart the license manager daemon**; this also applies if you update from HALCON 6.1 or 6.1.1 to HALCON 6.1.3. See section 2.3.4.3 for detailed information.

- **other version:** If the setup detects a release of another HALCON version, e.g., if the setup of HALCON 6.1.1 detects HALCON 6.0.3, it asks whether you want to keep the old version. For more information about switching between multiple HALCON versions please refer to section 2.1.5.

The setup program also checks whether you have installed ActivVisionTools, and whether the installed version is compatible to the current HALCON version. Please refer to section 2.1.6 for more information.

After all these checks, the installation wizard allows to specify whether you would like to install

- the full HALCON version (`Compact`, `Custom`, `Typical`[1]),
- the runtime version only (`Runtime`), or
- just the demo version `hdevelop_demo.exe` (`Demo`).

Note that you can install additional parts of HALCON at a later time by inserting the CD again and selecting the parts you need.

After this selection, the setup program asks whether to install the driver programs, which are necessary if you want to use a dongle license. Section 2.3.5 provides detailed information about dongle drivers, including how to install them manually if you didn't let HALCON do it.

The next dialog asks whether the computer is to act as the *floating license server*. In this case, the setup program installs the so-called *license manager daemon*, a system service that manages your floating licenses. Note that when using floating licenses, you need to install the license manager daemon only on one computer: the license server. Please refer to section 2.3.4 for more information about floating licenses, e.g., how to install the license manager daemon manually.

After some further questions the actual installation starts.

2.1.2 Installing HALCON Under UNIX

To install HALCON on UNIX systems, mount the CD, e.g., on the directory `/cdrom`. On most systems, you need `root` rights to do so. Note that on some systems, most notably Linux, the default mount entry, usually in `/etc/fstab`, does not allow user to execute programs on a CD. In such cases, you have to mount the CD explicitly with a command similar to the following:

```
mount /dev/cdrom /cdrom
```

For the installation, start the shell script `install-unix` which is located in the top-level directory of the CD. This script will ask you in which directory you want to install HALCON;

[1] Please note, that if you choose `Typical`, most of the image sequences are not installed. This means that example programs based on such an image sequence cannot be run. A quick remedy in such a case is to mount the HALCON CD again, as the example programs also look there for the images. Of course, you can also install additional parts of HALCON at a later time.

the environment variable HALCONROOT has to be set to this directory later, see section 2.4.2. Furthermore, the script asks whether to install various components of HALCON.

Since all directories and files on the CD are read-only, you may get some warnings about changed permissions if you run the installation script as an ordinary user (as root, no warnings of this kind should appear). Furthermore, on some systems you may get complaints about the fact that the CD contains files with file names longer than 32 characters.

Note, that the installation script checks whether your system meets the requirements for running HALCON (see section 1.2).

After the installation, several environment variables need to be set in order for HALCON to work. See section 2.4.2 for details.

Note, that you can install additional parts of HALCON at any time by mounting the CD again and copying the corresponding directories and files to the diectory where you installed HALCON. To copy directories, open a shell, change into the root directory on the CD, and type

```
tar -cf - <directory_to_be_copied> | ( cd $HALCONROOT; tar -xf - )
```

If you are using floating licenses, please note the following: After installing HALCON on the computer acting as the license server for the first time, you must install and start the license manager daemon as described in section 2.3.4.2. If you update from an HALCON 6.1 or 6.1.1 to HALCON 6.1.2 or 6.1.3, you must **restart the license manager daemon**; see section 2.3.4.3 for detailed information.

2.1.3 Updating HALCON (Windows NT/2000/XP only)

For Windows NT/2000/XP systems, there is a special mechanism which lets you update HALCON to a newer maintenance release of the same version, e.g., from HALCON 6.1 to HALCON 6.1.1 or 6.1.3. Please refer to the HALCON download area (http://www.mvtec.com/halcon/download) for more details.

Special Information for Users of Floating Licenses

If you are using floating licenses, please note the following: Before extracting the ZIP file on the computer acting as the license server, you must **stop the license manager daemon** as described in section 2.3.4.1. Otherwise, you will get an error message during the extraction, because the two files mvtecd.exe and lmgrd.exe cannot be replaced while the daemon is running. In this case, stop the daemon and repeat the extraction.

After the extraction, you must restart the license manager daemon (see section 2.3.4.3).

2.1.4 The Installed File Structure

Let's take a look at the installed file structure in the directory %HALCONROOT%. In the following, the most important directories and files are described briefly. Please note, that depending on your installation, not all directories will be present.

- `FLEXlm`: This directory contains programs used for licensing (see section 2.3), in subdirectories corresponding to the different platforms.
- `bin`: This directory contains HALCON programs, for example HDevelop (Windows: `hdevelop.exe`; UNIX: `hdevelop`), again in subdirectories corresponding to the different platforms. For Windows, this directory also contains the DLL version of the HALCON libraries and the libraries for the supported frame grabbers interfaces.
- `calib`: This directory contains description files for the calibration plates, which you can use to calibrate your camera.
- `doc\pdf`: Here, you find the PDF version of the user's manuals (subdirectory `manuals` and of the reference manuals (subdirectory `reference`).
- `examples`: The subdirectories of this directory contain example programs for the different parts of the HALCON system:
  - ▷ `application_guide`: Examples referenced in the Application Guide.
  - ▷ `c`: Examples for using HALCON within the programming language C (see also the HALCON/C User's Manual).
  - ▷ `cpp`: Examples for using HALCON within the programming language C++ (see also the HALCON/C++ User's Manual).
  - ▷ `c#`: Examples for using HALCON within the programming language C# (see also the HALCON/COM User's Manual).
  - ▷ `delphi`: Examples for using HALCON within Borland Delphi.
  - ▷ `fg_integration`: Example programs for frame grabber interfaces (see also the Frame Grabber Integration Programmer's Manual).
  - ▷ `extension_package`: The example user package `halconuser` (see also the Extension Package Programmer's Manual).
  - ▷ `hdevelop`: Examples for using HDevelop, together with the example programs described in the manual Getting Started with HALCON (subdirectory `Manuals\Getting Started`) and in the HDevelop User's Manual (subdirectory `Manuals\HDevelop`).
  - ▷ `mfc`: Examples for using HALCON together with MFC (see also the HALCON/C++ User's Manual and the HALCON/COM User's Manual).
  - ▷ `motif`: Examples for using HALCON together with Motif (see also the HALCON/C++ User's Manual).
  - ▷ `vb`: Examples for using HALCON within Visual Basic, together with the example programs described in the HALCON/COM User's Manual .
  - ▷ `vb.net`: Examples for using HALCON within Visual Basic .NET (see also the HALCON/COM User's Manual).

  Please note, that the examples should not be used directly for two reasons: First, on most platforms only the user who installed HALCON is allowed to save a (modified) example program. More importantly, on some operating systems not all users have the permission

to create new files in the example subdirectories; this causes errors in those example programs which contain operators that write data to files. To experiment with examples we therefore recommend to create a private copy in your own working directory.

- `filter`: This directory contains predefined filter masks.
- `images`: This directory contains example images and, in subdirectories, image sequences. These images are used by the example programs described above.
- `include`: This directory contains the header files which are necessary to use HALCON within the programming languages C or C++.
- `lib`: This directory contains the HALCON libraries and the libraries for the supported frame grabbers interfaces (Windows: file extension `.lib`; UNIX: file extension `.so`), again in subdirectories corresponding to the different platforms.
- `license`: The license file `license.dat` must be placed in this directory (see section 2.3).
- `lut`: This directory contains predefined look-up tables.
- `ocr`: This directory contains trained fonts.

2.1.5 Switching Between Different HALCON Versions

You can install multiple HALCON versions on a computer and then switch between them. **Under Windows NT/2000/XP,** you must adapt those environment variables that are set during the installation, i.e., `%PATH%`, `%HALCONROOT%`, and `%HALCONIMAGES%`, and those you set yourself (e.g., `%HALCONEXTENSIONS%`). Please refer to section 2.4.1 for more information about setting environment variables.

If you are using the HALCON/COM interface, you must also re-register the corresponding DLL `halconx.dll`, for example as follows: Open a Windows Command Prompt and change into the subdirectory `bin\i586-nt4` of the root directory of your "old" HALCON installation. Unregister `halconx.dll` by typing

```
regsvr32 /u halconx.dll
```

Then change into the corresponding subdirectory of your other HALCON installation and register its `halconx.dll` by typing

```
regsvr32 halconx.dll
```

As an alternative to the Command Prompt, you can unregister and register `halconx.dll` via the dialog `Start` ▷ `Run` together with the Windows Explorer: In the latter, "open" the directory `bin\i586-nt4` of the root directory of your old HALCON installation. Now, type `regsvr32 /u` the dialog `Run` and then drag and drop `halconx.dll` from the Explorer into the dialog, where it automatically appears with the full path. To execute the command, click `OK`. Then, open the directory `bin\i586-nt4` of the root directory of the other HALCON installation in the Explorer, type `regsvr32` in the dialog `Run`, drag and drop `halconx.dll` from the Explorer into the dialog, and again click `OK`.

Under UNIX, you switch to another HALCON version by setting the environment variables `$HALCONROOT` (and derived variables like `$HALCONIMAGES`), `$PATH`, and `$LD_LIBRARY_PATH` accordingly (see also section 2.4.2).

2.1.6 Information for Users of ActivVisionTools

Only ActivVisionTools 2.1 and 2.2 are based on HALCON 6.1, while the older versions 1.0 to 2.0 are all based on HALCON 6.0 (or HALCON 6.0.1); thus, by installing HALCON 6.1.x you would disable such an older ActivVisionTools installation! Therefore, the setup program of HALCON 6.1.x checks whether there is an ActivVisionTools installation on your computer. Depending on the version, the following action is performed:

- **ActivVisionTools 2.1 or 2.2**
  If the setup of HALCON 6.1.1 or higher detects ActivVisionTools 2.1 or 2.2, no further action is required, as this version is fully compatible. Unfortunately, the setup of **HALCON 6.1 wrongly warns that ActivVisionTools 2.1 is not compatible**; you can safely ignore this warning and proceed.

- **ActivVisionTools 2.0**
  If HALCON 6.1.x detects ActivVisionTools 2.0, it offers to replace the corresponding OCX `ActivVTools.ocx` with a new one which is compatible to HALCON 6.1.x. Typically, you will choose this option. If not, you can replace it manually as follows: Open a Windows Command Prompt and change into the subdirectory `bin\i586-nt4` of the root directory of your ActivVisionTools installation. Unregister `ActivVTools.ocx` by typing

  ```
  regsvr32 /u ActivVTools.ocx
  ```

  Then delete the OCX (or rename it) and replace it by the new one, which can be found on the CD in the directory `misc\i586-nt4\avt20`, or in the ActivVisionTools download area (`http://www.activ-vision-tools.com/download`). Register the new OCX by typing

  ```
  regsvr32 ActivVTools.ocx
  ```

  As an alternative to the Command Prompt, you can unregister and register the OCX via the dialog `Start` ▷ `Run` together with the Windows Explorer: In the latter, "open" the directory `bin\i586-nt4` of the root directory of your ActivVisionTools installation. Now, type `regsvr32 /u` the dialog `Run` and then drag and drop `ActivVTools.ocx` from the Explorer into the dialog, where it automatically appears with the full path. To execute the command, click `OK`. Then, replace the OCX with the new open, type `regsvr32` in the dialog `Run`, drag and drop `ActivVTools.ocx` from the Explorer into the dialog, and again click `OK`.

  If you decided to switch back to an older HALCON version as described in section 2.1.5, you must of course unregister the new OCX and register the old one; if you deleted it you can recover it from the corresponding directory on the ActivVisionTools 2.0 CD.

- **ActivVisionTools 1.0-1.3**
  In contrast to ActivVisionTools 2.0, **ActivVisionTools 1.0 to 1.3 cannot be used together with HALCON 6.1.x**, i.e., there is no compatible OCX available. If the setup program

of HALCON 6.1.x detects such an ActivVisionTools version, e.g., ActivVisionTools 1.3, it therefore only warns that by continuing you will disable your ActivVisionTools installation. If you still want to use your ActivVisionTools installation, you must also keep your old HALCON 6.0.x installation and switch back to it as described in section 2.1.5. Note that if you only want to evaluate HALCON 6.1.x, you can minimize the switching effort by installing only the demo version: In this case there is no need to re-register the HALCON/COM interface library `halconx.dll`.

2.2 Uninstallation

2.2.1 Uninstalling HALCON Under Windows NT/2000/XP

There are multiple ways to uninstall HALCON; please note that not all are available for older versions of HALCON:

1. In the system control panel choose `Add/Remove Programs`.
2. If the HALCON release you want to uninstall is newer than version 5.1: Select `Start` ▷ `Programs` ▷ `MVTec HALCON` ▷ `Uninstall HALCON`.
3. From version 5.2 on, the HALCON setup program checks whether there is an old version of HALCON and allows you to uninstall it. This is the preferred way since it avoids the problem with the path variable described below. Note, however, that this method does not work if you want to uninstall an older maintenance release based on the same version of HALCON.

Typically, this is all you have to do. If you encounter any problems, please refer to section 6.5.2.

Note, that the uninstallation removes exactly those files which were installed. This has two implications: If you added files after the installation, e.g., new frame grabber interfaces, extension packages, images, or manuals, these files and the corresponding directories will “survive” the uninstallation. On the other hand, if you only modified a file, e.g., an example, without changing its name the uninstallation will remove it nevertheless; you might therefore want to copy such files to another directory before starting the uninstallation.

The uninstallation warns if it encounters DLLs or executables that might be or are actually used by another application. The warnings regarding `halconx.dll` and `HFGDirectShow.dll` can safely be ignored, i.e., the files can be removed. In contrast, warnings regarding `mvtecd.exe` and `lmgrd.exe` are serious; they indicate that the license manager daemon was installed manually but not uninstalled. In this case, we recommend to abort the uninstallation process, uninstall the license manager daemon manually as described in section 2.3.4.1, and then restart the uninstallation of HALCON.

The uninstallation process will not remove any *user-specific settings*. This means that registry entries concerning, e.g., the layout of HDevelop or its file history, will be left in the category `HKEY_CURRENT_USER` ▷ `Software` ▷ `MVTec` ▷ `HALCON`. You may remove these entries manually without risk. Furthermore, it does not remove the dongle drivers as they might be needed by another application; section 2.3.5 describes how to remove them manually.

Special Information for HALCON 6.0.2

From version 6.0.2 on, HALCON requires a newer version of the dongle driver programs from GLOBEtrotter (see also section 2.3.5). However, the uninstallation process does not uninstall the old dongle driver; as a consequence, during the installation of HALCON 6.0.2 the new driver cannot be installed (even if the setup program might state that the installation was successful!).

Therefore, you must **uninstall the dongle driver manually before uninstalling HALCON!** Please refer to section 2.3.5.1 for more information.

2.2.2 Uninstalling HALCON Under UNIX

To uninstall an existing HALCON system, just remove the contents of the HALCON base directory `$HALCONROOT` and all its subdirectories, e.g., by executing

```
rm -rf $HALCONROOT
```

Furthermore, remove the subdirectory `.hdevelop` of the directory referenced by the environment variable `HOME` (see section 2.4.2); HDevelop creates this directory to save options, window positions, and the file history.

The uninstallation process will not remove any *user-specific settings*. This means that environment variables remain unchanged and have to be adapted or deleted manually.

If you called the operator `check_par_hw_potential` from **Parallel HALCON 6.0 beta** to initialize Parallel HALCON (see section 5.1.1), the file `.halcon_par_info` which contains the extracted information about the host computer will be left in the directory referenced by the environment variable `HOME` (see section 2.4.2).

2.3 Licensing

HALCON checks whether the product is licensed to the user with the help of the FLEXlm license manager[2] package from GLOBEtrotter. In this section a brief summary of the default procedure to obtain and install a license will be given.

The first step is of course to *select the computer* on which (in case of a nodelocked license) you want to use HALCON on or which (in case of a floating license) is to act as the license server, i.e., which keeps track of how many licenses of HALCON are currently in use. Note, that a computer need not be a "server" in the sense that they have to be a "big" server machine or have a special kind of operating system, e.g., Windows NT Server, installed. If you want to run HALCON on a stand-alone computer, the license server must be this computer. If you run HALCON on a network any computer on the network can serve as a license server.

In order to obtain a license for HALCON, you have to *extract identifying information* about this computer (see section 2.3.1 for more details) and send it to your local distributor. If you want to obtain a runtime license, you have to inform your local distributor which HALCON *modules* you want to use. Please refer to section 2.3.2 for more information.

You will then receive a *license file*. Section 2.3.3 describes how to install this file on your system. Section 2.3.4 contains additional information for the case you want to use a floating license.

2.3.1 Extracting Identifying Information

The standard method for identifying an computer requires that the computer of your choice is equipped with a *network card*. If you are using Windows NT/2000/XP and if your computer is equipped with a *Pentium III processor*, it can be identified by the so-called CPU ID as well.

Under Windows NT/2000/XP, you can also use a *hardware dongle*. In this case, the license will be coupled to this dongle, i.e., you can use HALCON on another computer by moving the dongle. This has the advantage that you don't commit yourself to using a certain computer. You can use dongles both for nodelocked and for floating licenses. In the latter case, the dongle is used for identifying the computer which acts as the license server. You can obtain such a dongle from your local distributor. The dongle will be delivered together with the corresponding license file. See section 2.3.5 for more information regarding the use of dongles.

2.3.1.1 Extracting Information Using HDevelop

The easiest method to extract identifying information is to start the HDevelop demo version (which is always installed). You start it under Windows NT/2000/XP, call `Start ▷ Programs ▷ MVTec HALCON ▷ HDevelop Demo`; under UNIX, call `hdevelop_demo` from a shell. Now, select the menu item `Help ▷ About`. A dialog as depicted in figure 2.1 appears. At the bottom, it shows all the information available on your computer, in the example the three so-called host IDs corresponding to a network card, a Pentium III, and a dongle. In most cases, you will see only one ID.

[2] The full documentation of FLEXlm can be obtained from the FLEXlm end user manual available at `http://www.globetrotter.com/manual.htm`.

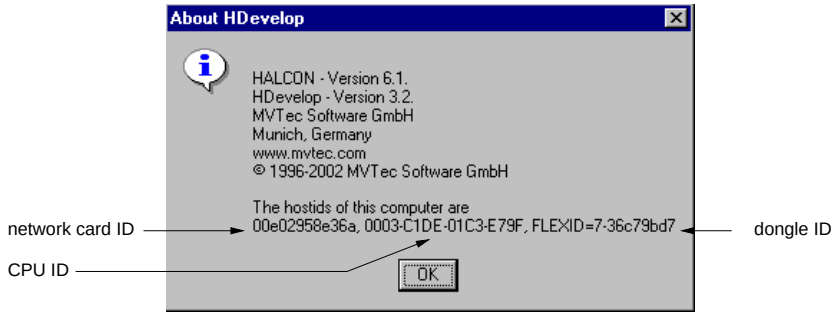

Figure 2.1: Identifying information in the HDevelop window `About`.

To obtain a license based on a network card or a Pentium III CPU, send the corresponding ID to your local distributor together with the hostname of this machine in your network (for example, `halconserver`). In the case of a dongle license, this is not necessary, as you will receive the license file already together with the dongle.

If HDevelop fails to detect any host IDs although your computer does have a network card, a Pentium III, or a dongle, please try to extract the host IDs manually as described in the following section. If IDs like `"ffffffff"`, `"0"`, or `""` appear, please consult section 6.5.3 for troubleshooting.

2.3.1.2 Extracting Information Using `lmhostid`

As a (more tedious) alternative, you can extract these IDs by using the program `lmhostid` shipped together with the license manager FLEXlm. Under Windows NT/2000/XP, open a Windows Command Prompt[3]. Under UNIX, open a shell, change into the directory `$HALCONROOT/FLEXlm` and then into the subdirectory corresponding to your operating system (e.g., `i586-linux2.2` or `sparc-sun-solaris7`).

To identify a computer by its network card, type `lmhostid -ether` (or just `lmhostid`). Following the example of the previous section, the output might look like this on a Windows system:

```
> lmhostid -ether
lmhostid - Copyright (C) 1989-2000 Globetrotter Software, Inc.
The FLEXlm host ID of this machine is "00e02958e36a"
```

Send the ID, in this example the string `"00e02958e36a"`, to your local distributor together with the hostname of this machine in your network (for example, `halconserver`). If `lmhostid` returns `"ffffffff"` or `"0"` please consult section 6.5.3.1 for troubleshooting.

To identify a computer by its (Pentium III) CPU number (Windows NT/2000/XP only), type `lmhostid -cpu64`. The output now might look like this:

```
> lmhostid -cpu64
lmhostid - Copyright (C) 1989-2000 Globetrotter Software, Inc.
The FLEXlm host ID of this machine is "0003-C1DE-01C3-E79F"
```

[3] Do not start the program from the Explorer. You *must* use a Command Prompt.

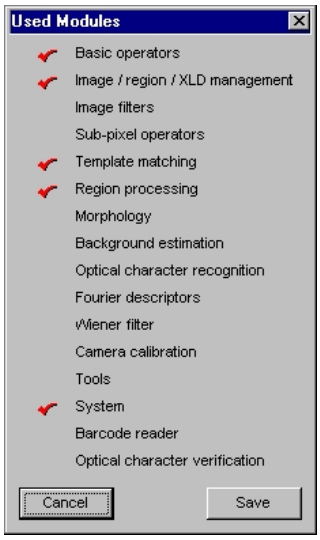

Figure 2.2: Used modules in the example program in chapter 3.

Send the ID, in this example the string `"0003-C1DE-01C3-E79F"`, to your local distributor together with the hostname of this machine in your network (for example, `halconserver`). If `lmhostid` returns `""`, the reason probably is that the service providing the CPU ID is disabled in the computer's BIOS. You can check and enable this service in the BIOS configuration mode; this mode can only be entered during the booting process. Please consult section 6.5.3.1 for troubleshooting.

To check the dongle ID (Windows NT/2000/XP only), type `lmhostid -flexid`. The output now might look like this:

```
> lmhostid -flexid
lmhostid - Copyright (C) 1989-2000 Globetrotter Software, Inc.
The FLEXlm host ID of this machine is "FLEXID=7-36c79bd7"
```

Note, that this number is also written on the dongle.

2.3.2 Runtime Licenses and HALCON Modules

HALCON operators are grouped into so-called *modules*. Some modules, e.g., 'Basic Operators' or 'Image / Region / XLD Management', are used in all HALCON applications, others like 'Background Estimation' or '1D Bar Code Reader' will only be needed in special applications. While the development version of HALCON automatically includes all modules, you can limit a runtime version to the modules you actually need.

You can check which modules are used by an application in two ways:

1. If the application is running in HDevelop (see chapter 3 for more information), select the menu item `File` ▷ `Modules...` which will open a pop-up dialog as depicted in figure 2.2. Click `Save` to save the required modules in a file with the extension `.mod` in the currently used directory.

2. If the application is written in a programming language (C, C++, COM), insert the operator `get_modules` (see the corresponding entry in the HALCON Reference Manuals for more information) at the end of the program.

Send the thus determined module names to your local distributor when requesting a runtime license.

Please note that the number of modules depends on the used environment; for example, within HDevelop an application may need less modules than after exporting it to Visual Basic. Thus, we recommend to **determine the number of modules in the environment used for the final application**.

2.3.3 Installing the License File

Your local distributor will supply you with a *license file*. This file must be put into the directory `%HALCONROOT%\license`[4] and be renamed to `license.dat`, if necessary; `%HALCONROOT%` is the HALCON base directory you have chosen during the installation. If you are using the floating license scheme, you must copy the license file to all computers you installed HALCON on, i.e., the computer acting as the license server and all computers where HALCON is to be used, and then restart the license manager daemon as described in section 2.3.4.3.

If you upgrade HALCON to a newer version, e.g., from HALCON 6.0.x to HALCON 6.1.x, your distributor provides you with a so-called *upgrade license file*. In this case, you must append the content of this file at the end of the old license file `%HALCONROOT%\license\license.dat` (see figure 2.5 for an example). Please note that some editors insert special characters, which cannot be interpreted by FLEXlm. Under Windows systems, we recommend to use WordPad. Due to a bug in the FLEXlm software, you might encounter problems if you upgrade twice, e.g., from HALCON 5.2 to 6.0 and then to 6.1. In this case, please contact your distributor for further instructions.

```
##########################################
# MVTec Software GmbH (ID: 00e02958e3b6) #
##########################################
FEATURE MVTec_Halcon mvtecd 6.1 01-jan-0000 uncounted BC4D86743889FC4CFAC2 \
  VENDOR_STRING=65535 HOSTID=00e02958e3b6 ck=109
FEATURE MVTec_HDevelop mvtecd 6.1 01-jan-0000 uncounted \
  5CFD86941816A696B16F VENDOR_STRING=65535 HOSTID=00e02958e3b6 ck=30
```

Figure 2.3: Nodelocked development license, bound to network card.

```
################################################
# MVTec Software GmbH (ID: FLEXID=7-b285ff7f) #
################################################
FEATURE MVTec_Halcon mvtecd 6.1 01-jan-0000 uncounted 3C574319AF86C4A5DE4A \
  VENDOR_STRING=65535 HOSTID=FLEXID=7-b285ff7f ck=35
```

Figure 2.4: Nodelocked runtime license, bound to dongle.

[4] See the FLEXlm end user manual on how to configure this location.

original license file (HALCON 6.0):

```
########################################
# MVTec Software GmbH (ID: 00e02958e3b6) #
########################################
FEATURE MVTec_Halcon mvtecd 6.0 01-jan-0000 uncounted 9C6D4634F08A932DBC2D \
  VENDOR_STRING=65535 HOSTID=00e02958e3b6 ck=82
FEATURE MVTec_HDevelop mvtecd 6.0 01-jan-0000 uncounted \
  7CADE63412EF3451B596 VENDOR_STRING=65535 HOSTID=00e02958e3b6 ck=34
```

upgrade license file (HALCON 6.0 to HALCON 6.1):

```
########################################
# MVTec Software GmbH (ID: 00e02958e3b6) #
########################################
UPGRADE MVTec_Halcon mvtecd 6.0 6.1 01-jan-0000 uncounted \
  3C0D76C4ADF2BFE51017 VENDOR_STRING=65535 HOSTID=00e02958e3b6 ck=54
UPGRADE MVTec_HDevelop mvtecd 6.0 6.1 01-jan-0000 uncounted \
  1CCDC6246E6E497BB0B4 VENDOR_STRING=65535 HOSTID=00e02958e3b6 ck=48
```

resulting license file after appending the upgrade keys:

```
########################################
# MVTec Software GmbH (ID: 00e02958e3b6) #
########################################
FEATURE MVTec_Halcon mvtecd 6.0 01-jan-0000 uncounted 9C6D4634F08A932DBC2D \
  VENDOR_STRING=65535 HOSTID=00e02958e3b6 ck=82
FEATURE MVTec_HDevelop mvtecd 6.0 01-jan-0000 uncounted \
  7CADE63412EF3451B596 VENDOR_STRING=65535 HOSTID=00e02958e3b6 ck=34
UPGRADE MVTec_Halcon mvtecd 6.0 6.1 01-jan-0000 uncounted \
  3C0D76C4ADF2BFE51017 VENDOR_STRING=65535 HOSTID=00e02958e3b6 ck=54
UPGRADE MVTec_HDevelop mvtecd 6.0 6.1 01-jan-0000 uncounted \
  1CCDC6246E6E497BB0B4 VENDOR_STRING=65535 HOSTID=00e02958e3b6 ck=48
```

Figure 2.5: Upgrading a license from HALCON 6.0 to HALCON 6.1.

Figures 2.3 and 2.4 show examples for different types of license files for nodelocked licenses; an example file for a floating license can be found in the following section. The lines starting with `FEATURE` are called *license keys*. As you can see, they contain the version number of HALCON (in the example files: `6.1`). However, a license is not exclusively bound to this release. First, a license is *downward compatible*, i.e., a license for HALCON 6.1 is also valid for HALCON 6.0. Secondly, a license is *upward compatible within a version number*, i.e., licenses for HALCON 6.1 are also valid for HALCON 6.1.1. If you upgrade to a newer version, however, you need corresponding upgrade license keys (lines starting with `UPGRADE`); figure 2.5 depicts an example for upgrading a license from HALCON 6.0 to HALCON 6.1.

2.3.4 Using Floating Licenses

The previous sections already mentioned some issues concerning the use of floating licenses: First, you must select one computer in your network which is to act as the *license server*, i.e., watch over the number of HALCON licenses currently used; on this computer, a special program called the *license manager daemon* must be installed and started (see the sections below). Secondly, the license file supplied by your distributor must be copied to all computers you installed HALCON on, i.e., not only those you want to use HALCON on but also the license server. Note that if you get a new license, you must restart the license manager daemon after replacing the license files (see section 2.3.4.3). The same is true if you modify parts of the license file.

Let's take a closer look at an example license file for a **floating license** in figure 2.6: The line starting with `SERVER` tells FLEXlm the name of the host computer acting as the license server (in the example: `halconserver`), its identifying information (in the example: network card ID), and the port number (in the example: 27000).

If you didn't send the name of the license server host computer to your distributor when requesting the license, the corresponding field contains the entry `unknown`; in this case, please enter the correct host name instead. Another reason for modifying the entry for the host name is, e.g., if you are using a dongle-bound license and want to switch the dongle (and the license server) to another computer in your network. The same applies if you change the name of your host computer or, in the case the license is bound to a network card ID, if you move the network card to another computer.

You may also customize the port number. This may be necessary for example if the default port number is used already by another software in your computer network. Note, that on many systems all ports < 1024 are privileged and can only be used by privileged accounts!

Please keep in mind that the information contained in the line starting with `SERVER` is used in two ways: When you start HALCON on an arbitrary computer in your network, it uses the host name and the port number to locate and contact the license server. On the computer acting as the license server, the port number is used when starting and configuring the license manager daemon. Therefore, it is very important that this line is identical in all copies of the license file in your network!

Depending on where you have installed HALCON on the computer acting as the license server, you may have to customize the path to the daemon `mvtecd`, which is in charge of managing the HALCON licenses. Normally, the path will be

```
############################################
# MVTec Software GmbH (ID: 00e02958e3b6) #
############################################
SERVER halconserver 00e02958e3b6 27000
DAEMON mvtecd C:\Progra~1\MVTec\HALCON\FLEXlm\i586-nt4\mvtecd
FEATURE MVTec_Halcon mvtecd 6.1 01-jan-0000 1 1CBD8604021DC9DBC868 \
  VENDOR_STRING=65535 ck=43
FEATURE MVTec_HDevelop mvtecd 6.1 01-jan-0000 1 4C2DB644BC603179E58F \
  VENDOR_STRING=65535 ck=80
```

Figure 2.6: Floating license, bound to network card.

%HALCONROOT%\FLEXlm\%ARCHITECTURE%\mvtecd (see section 2.4 for information about the environment variable ARCHITECTURE). However, since you cannot use environment variables in the license file, you must supply this path manually. Note that paths including blanks are not handled properly under Windows NT/2000/XP: Thus, if you have installed HALCON to a directory like C:\Program Files\MVTec\HALCON you will have to use the short path C:\Progra~1\MVTec\HALCON instead. You can query short path names as follows: Open a Windows Command Prompt, change into the directory that contains the directory or file whose short name is searched for (here: C:), and then type

```
dir /x
```

Note that the daemon mvtecd opens a second port. By default, this port is selected by the operating system, and thus its number can change. Especially when using a firewall, you might need to specify the port number explicitly. For this, append the string port=*number* to the line starting with DAEMON, for example as follows:

```
DAEMON mvtecd C:\Progra~1\MVTec\HALCON\FLEXlm\i586-nt4\mvtecd port=28000
```

Finally, you have to make sure that the license manager daemon is installed and started successfully.

2.3.4.1 (Un-)Installing the License Manager Daemon Under Windows NT/2000/XP

On Windows NT/2000/XP systems, you can let the setup program install the license manager daemon, which will then be started automatically at boot time as the system service 'HALCON Licenses'.

To check whether the daemon was installed successfully, open the Windows dialog showing the state of the installed services. Under Windows NT, this dialog can be opened via Start ▷ Settings ▷ Control Panel ▷ Services, under Windows 2000 and Windows XP via Start ▷ Settings ▷ Control Panel ▷ Administrative Tools ▷ Component Services ▷ Services. If the daemon was installed successfully, the dialog contains the entry HALCON Licenses.

Installing the License Manager Daemon Manually

If you did not install the license manager daemon via the setup, or if its installation failed, you can install it manually at a later time as described below. Note that you need administrator privileges for this procedure. Open a Windows Command Prompt, change into the directory %HALCONROOT%\FLEXlm\i586-nt4, and type (*one* long command line):

```
"installs" -n "HALCON Licenses"
  -c "%HALCONROOT%\license\license.dat"
  -l "%HALCONROOT%\license\license.log"
  -e "%HALCONROOT%\FLEXlm\i586-nt4\lmgrd.exe"
```

with %HALCONROOT% being the HALCON base directory you have chosen during the installation. For example, if you have installed HALCON in the directory C:\Program Files\MVTec\HALCON, you type

```
"installs" -n "HALCON Licenses"
  -c "C:\Program Files\MVTec\HALCON\license\license.dat"
  -l "C:\Program Files\MVTec\HALCON\license\license.log"
  -e "C:\Program Files\MVTec\HALCON\FLEXlm\i586-nt4\lmgrd.exe"
```

The quotes are necessary to handle paths that contain blanks like the one above properly.

To check whether the installation succeeded, (re-)open the Windows dialog showing the state of the installed services (see above), which now should contain the entry HALCON Licenses (or, to be more exact, an entry with the name you specified with the option -n or FLEXlm license manager if you leave out this option).

After the installation, the daemon is not started automatically. If you have administrator privileges, you can start it directly in the dialog by selecting it and then clicking the start button or icon; if this fails, please check whether the entries in the license file are correct. The license manager daemon is started automatically whenever you (re-)boot the computer.

Note that if you installed the license manager daemon manually, you must also uninstall it manually before you uninstall HALCON, otherwise it remains installed.

Uninstalling the License Manager Daemon

Please note that for the following procedure you need administrator privileges.

Before you can uninstall the license manager daemon, you must first stop it: Open the Windows dialog showing the state of the installed services (see above), select the entry HALCON Licenses and then click the stop button or icon. Note that under Windows 2000 and Windows XP an error message may appear, which can safely be ignored.

Now, open a Windows Command Prompt, change into the directory %HALCONROOT%\FLEXlm\i586-nt4, and type:

```
installs -r -n "HALCON Licenses"
```

To check whether the uninstallation succeeded, re-open the services dialog, which should not contain an entry HALCON Licenses anymore.

2.3.4.2 Installing the License Manager Daemon Under UNIX

On UNIX systems, the license manager daemon lmgrd must be started from the appropriate startup file (called e.g. /etc/init.d/boot.local, /sbin/init.d/boot.local, /etc/rc.boot, /etc/rc.local, or /etc/localrc, please consult your system's documentation). Add the following (long) line to this file (with suitable path to lmgrd):

```
/etc/lmgrd -c $HALCONROOT/license/license.dat
    > $HALCONROOT/license/license.log 2>&1 &
```

where $HALCONROOT is the HALCON base directory you have chosen during the installation. Please note, that lmgrd will only work properly when started with root privileges!

2.3.4.3 Restarting the License Manager Daemon

Whenever you replace a floating license or modify it, you must restart the license manager daemon. One possible method is to reboot the computer acting as the license server. If you have administrator privileges, you can also restart the daemon manually. On Windows systems, open the dialog showing the state of the installed services (Windows NT: `Start` ▷ `Settings` ▷ `Control Panel` ▷ `Services`, Windows 2000 and Windows XP: `Start` ▷ `Settings` ▷ `Control Panel` ▷ `Administrative Tools` ▷ `Component Services` ▷ `Services`), select the entry `HALCON Licenses` and then stop and start it again.

On UNIX systems, you stop the process `lmgrd` and then restart it with the line used in the startup file (see section 2.3.4.2).

Another reason for restarting the license manager daemon is when you update to a HALCON release that uses with a newer version of the FLEXlm license manager software, e.g., from HALCON 6.1.1 to 6.1.2 or 6.1.3.

2.3.5 Using a Dongle

Let's take a closer look at hardware dongles. As already mentioned, you can use dongles for licensing only under Windows NT/2000/XP. From version 6.0.2 on, HALCON supports not only dongles connected to the parallel port but also USB dongles. Dongles for the parallel port have IDs starting with `'FLEXID=6-'` or `'FLEXID=7-'`, while USB dongles have IDs starting with `'FLEXID=9-'`. Please note that you cannot use any dongle but only those supplied by MVTec via your distributor.

2.3.5.1 Dongles for the Parallel Port

As described in section 2.1.1, you can let HALCON install the driver programs necessary for using dongles. You can check the success of this installation in the following system dialog, which should contain an entry called `Sentinel`.

- **Windows NT** : `Start` ▷ `Settings` ▷ `Control Panel` ▷ `Devices`.
- **Windows 2000, Windows XP** : `Start` ▷ `Programs` ▷ `Accessories` ▷ `System Tools` ▷ `System Info` ▷ `Software Environment`, then select `Drivers` under Windows 2000 or `System Drivers` under Windows XP, respectively.

You can install, configure, and uninstall the dongle driver manually using an auxiliary program which is part of each HALCON installation. Open a Windows Command Prompt or the dialog `Start` ▷ `Run` and start the program

```
%HALCONROOT%\FLEXlm\i586-nt4\flexid6-7\win_nt\setupx86.exe
```

To install the driver, select the menu item `Functions` ▷ `Install`. Afterwards, reboot your computer. Then, the driver should appear in the dialog described above. **Please note, that you need administrator privileges to install the driver!** If you try to install the driver without administrator privileges, the setup program might falsely state that the installation was successful.

You might need to configure the driver if your computer has more than one parallel port.

Note that the HALCON uninstallation process does not uninstall the dongle driver as it might also be used by another application. The uninstallation removes the auxiliary program, though. Therefore, if you want to uninstall the driver, do so before uninstalling HALCON; of course, the program can still be found on the HALCON CD in the directory `FLEXlm\i586-nt4\flexid6-7\win_nt`.

Special Information for HALCON 6.0.2

As already mentioned in sections 2.1.3 and 2.2.1, you must pay special attention to the dongle driver when installing HALCON 6.0.2. We recommend the following procedure:

- Uninstall the old driver manually; the corresponding auxiliary program `setupx86.exe` can be found in the directory `%HALCONROOT%\FLEXlm\i586-nt4\dongle`.
- Now there are two ways to install HALCON 6.0.2:
  - Uninstall your old HALCON version as described in section 2.2.1, then install HALCON 6.0.2 together with the new dongle driver as described in section 2.1.1.
  - Use the update mechanism described in section 2.1.3; in this case you must install the dongle driver manually afterwards with the auxiliary program `setupx86.exe` located in the directory `%HALCONROOT%\FLEXlm\i586-nt4\flexid6-7\win_nt`.

If you uninstalled HALCON before uninstalling the old driver, the corresponding auxiliary program will be removed! You can recover it from a HALCON 6.0 CD (in the directory `FLEXlm\i586-nt4\dongle`); if you don't have a CD, we recommend to install your old HALCON version again.

2.3.5.2 Dongles for the USB Port

As described in section 2.1.1, you can let HALCON install the driver programs necessary for using dongles. You can check the success of this installation in the system dialog given in section 2.3.5.1, which should contain two entries called `Hardlock` and `HASP` (or similar).

Depending on your operating system, you can install, configure, and uninstall the dongle drivers manually using an auxiliary program which is part of each HALCON installation. Open a Windows Command Prompt or the dialog `Start` ▷ `Run` and execute the program `%HALCONROOT%\FLEXlm\i586-nt4\flexid9\hinstall.exe` in one of the following ways:

```
hinstall                  opens a dialog explaining how to use hinstall
hinstall -info            shows the status of the drivers
hinstall -i               installs the drivers
hinstall -remove          removes the drivers
```

Please note that you need administrator privileges to install the drivers!

Note that the HALCON uninstallation process does not uninstall the driver as they might also be used by another application. The uninstallation removes the auxiliary program, though. Therefore, if you want to uninstall the drivers, do so before uninstalling HALCON; of course, the program can still be found on the HALCON CD in the directory `FLEXlm\i586-nt4\flexid9`.

2.4 Configuration

Most of the configuration necessary to work with HALCON amounts to setting environment variables, e.g., to tell HALCON the directories where to find images or extension packages etc. These environment variables are described below. To work with Parallel HALCON, you need to initialize it once on each computer it is to be used on. This is described in section 5.1.1.

2.4.1 Configuring HALCON Under Windows NT/2000/XP

The installation program `Setup.exe` automatically sets the necessary environment variables, e.g., `%HALCONROOT%`, `%HALCONIMAGES%`, and `%HALCONEXTENSIONS%` (see below). To take a look at these setting, open the dialog `Start` ▷ `Settings` ▷ `Control Panel` ▷ System and select `Environment`. You can add or modify a variable by entering the name of a variable and the desired value. If a value consists of multiple items, as e.g. the variable `%PATH%` which may contain multiple directories, those items must be separated by *semicolons*. Please note that in order to modify variables set during the HALCON installation you need administrator privileges!

- `HALCONROOT`
  This is the most important environment variable. It designates the directory, where HALCON is installed. A typical path is, for example, `C:\Program Files\MVTec\HALCON`. According to this variable, the system switches to subdirectories, which are important for running HALCON. Some of them are listed below; the HALCON file structure is described in section 2.1.4.
  - `%HALCONROOT%\help`
    The operator data base is situated in this directory. It is accessible by all HALCON programs to obtain information about HALCON operators.
  - `%HALCONROOT%\doc\html\reference\hdevelop`
    HDevelop uses this directory for online help which can be displayed by a suitable HTML browser like Netscape Communicator.
  - `%HALCONROOT%\license`
    This directory contains the license file necessary for using HALCON.
  - `%HALCONROOT%\images`
    If the variable `HALCONIMAGES` (see below) is not set the system looks for image files in this directory.
- `HALCONIMAGES`
  To search for image files specified by a relative path, the system uses this environment variable. As a rule it contains several directory names, possibly including the CD ROM, separated by semicolons.
- `ARCHITECTURE`
  HALCON uses this variable to differentiate between the supported platforms (operating systems). On a Windows NT/2000/XP system, `%ARCHITECTURE%` is set to `i586-nt4`. The variable appears in different directory paths: Executable HALCON programs, e.g. `hdevelop.exe`, and DLLs, e.g. `halcon.dll`, reside in `%HALCONROOT%\bin\i586-nt4`. During installation, this path is automatically added to the environment variable `PATH` (see

below). The libraries which you need for linking programs, e.g. halcon.lib reside in the directory %HALCONROOT%\lib\i586-nt4.

- HALCONEXTENSIONS
  This is a list of directories in which user-defined extension operators (so-called extension packages) are kept. Each package consists of a number of operators linked into a shared library, plus the additional operator documentation in help-files and HTML files. See section 2.5 for information on how to install an extension package, and the Extension Package Programmer's Manual for details on creating your own extension packages.

- HALCONSPY
  If this environment variable is defined (regardless of the value) *before you start* a HALCON program, the HALCON debugging tool HALCON Spy is activated. This corresponds to call the HALCON operator set_spy with the parameters "mode","on" *within* a HALCON program. The main difference between the two modes for activating HALCON Spy is that by defining %HALCONSPY% it is possible to monitor an already linked HALCON program during runtime without modifications. For further information on how to use HALCON Spy and how to parameterize it via this environment variable please refer to section 6.4.

- PATH
  During the installation, the directories %HALCONROOT%\bin\i586-nt4 and %HALCONROOT%\FLEXlm\i586-nt4 are automatically added to the system variable PATH.

Please take a look at the file release_notes.html within the HALCON package for the latest information.

2.4.2 Configuring HALCON Under UNIX

Under UNIX, different shells offer different commands to set environment variables, e.g., setenv <variable> <value> or export <variable>=<value>. Please consult your shell's documentation for further information. If a value consists of multiple items, those items must be separated by *colons*.

Below, you find a list of environment variables used by the HALCON library and by HDevelop. We recommend to set them in a *login script* or a *shell resource script* (e.g., .cshrc or .profile):

Examples for entries in .cshrc	
setenv HALCONROOT	/usr/local/halcon
setenv ARCHITECTURE	i586-linux2.2
setenv PATH	...:$HALCONROOT/bin/$ARCHITECTURE/:...
setenv LD_LIBRARY_PATH	...:$HALCONROOT/lib/$ARCHITECTURE/:...
setenv HALCONIMAGES	$HALCONROOT/images

- HALCONROOT
  This is the most important environment variable. It designates the directory, where HALCON is installed. Typical paths are, for example, /usr/local/halcon or /usr/halcon.

ARCHITECTURE	Operating System (Platform)	Compiler
i586-linux2.2 i586-linux2.2-gcc32	Linux 2.2/2.4 on Intel Pentium (or compatible)	gcc 2.95 gcc 3.2/3.3
sparc-sun-solaris7	Solaris 7 on Sparc Workstations	CC
mips-sgi-irix6.5	IRIX 6.5 on SGI Workstations (Mips processors)	CC
alpha-compaq-osf5.1	Tru64 UNIX 5.1 [5] on Alpha processors	cxx

Table 2.1: Values of ARCHITECTURE for the currently supported UNIX platforms.

According to this variable the system switches to subdirectories, which are important for running HALCON. Some of them are listed below; the HALCON file structure is described in section 2.1.4.

- $HALCONROOT/help
  The operator data base is situated in this directory. It is accessible by all HALCON programs to obtain information about HALCON operators.
- $HALCONROOT/doc/html/reference/hdevelop
  HDevelop uses this directory for online help which can be displayed by a suitable HTML browser like Netscape.
- $HALCONROOT/license
  This directory contains the license file necessary for using HALCON.
- $HALCONROOT/images
  If the variable HALCONIMAGES (see below) is not set the system looks for image files in this directory.

- HALCONIMAGES
  To search for image files specified by a relative path, the system uses this environment variable. As a rule it contains several directory names separated by colons on UNIX systems.
- ARCHITECTURE
  This variable designates the used platform by an abbreviation (e.g., i586-linux2.2 or sparc-sun-solaris7; its syntax is: *processor-hardware_vendor-operating_system*). ARCHITECTURE appears in several directory paths: Executable HALCON programs, e.g. hdevelop, reside in $HALCONROOT/bin/$ARCHITECTURE. It is therefore useful to include the path $HALCONROOT/bin/$ARCHITECTURE in the environment variable PATH of a shell script. Shared libraries reside in the directory $HALCONROOT/lib/$ARCHITECTURE. Table 2.1 gives an overview of the currently supported UNIX platforms and the corresponding values of ARCHITECTURE.
- PATH
  If you want to start HDevelop from an arbitrary directory, you must include the HALCON program path $HALCONROOT/bin/$ARCHITECTURE in the system variable PATH.
- LD_LIBRARY_PATH
  Please include the HALCON library path $HALCONROOT/lib/$ARCHITECTURE in the sys-

[5] previously called DIGITAL UNIX

tem variable LD_LIBRARY_PATH. This is necessary both for running HDevelop and for creating stand-alone applications.

- HALCONEXTENSIONS
  This is a list of directories in which user-defined extension operators (so-called extension packages) are kept. Each package consists of a number of operators linked into a shared library, plus the additional operator documentation in help-files and HTML files. See section 2.5 for information on how to install an extension package, and the Extension Package Programmer's Manual for details on creating your own extension packages.

- HALCONSPY
  If this environment variable is defined (regardless of the value) *before you start* a HALCON program, the HALCON debugging tool HALCON Spy is activated. This corresponds to call the HALCON operator set_spy with the parameters "mode","on" *within* a HALCON program. The main difference between the two modes for activating HALCON Spy is that by defining %HALCONSPY% it is possible to monitor an already linked HALCON program during runtime without modifications. For further information on how to use HALCON Spy and how to parameterize it via this environment variable please refer to section 6.4.

- DISPLAY
  The system uses this environment variable to open windows. It is used in the same way as for other X applications.

- HOME
  This system variable points to your home directory. In Parallel HALCON 6.0 beta, the operator check_par_hw_potential which initializes Parallel HALCON (see section 5.1.1) saved the extracted information about the host computer in the file $HOME/.halcon_par_info .

2.5 Integrating a HALCON Extension Package

The HALCON Extension Package Interface allows to integrate newly developed image processing algorithms into HALCON in the form of so-called *extension packages*. The same mechanism is used by MVTec to extend the current HALCON release with additional functionality. Which extensions packages are currently available can be checked by selecting HDevelop's menu entry Help ▷ HALCON News (WWW), which connects to MVTec's WWW server.

This section describes how to integrate a (downloaded) package in order to use it within your HALCON system.

2.5.1 Installing an Extension Package

First, move the package to the directory %HALCONROOT% and unpack it there. Then, add the *complete* path of the package, e.g.,

```
%HALCONROOT%\packages\halconuser
```

to the environment variable HALCONEXTENSIONS. Note, that the delimiter between paths in an environment variable is a semicolon on Windows systems and a colon on UNIX systems.

> **Never change the name of a package or the corresponding names of the libraries or DLLs contained in a package.**

These names are encoded *within* the libraries/DLLs. If you change the names this information will not match any longer. Thus, the loader of the operating system will fail to open the dynamic libraries.

If the package contains images used, e.g., within example programs you might want to include the corresponding directory images within the package in the environment variable HALCONIMAGES (see section 2.4) to access those images without specifying a complete path.

2.5.2 Using an Extension Package Within HDevelop

In order to use a new package within HDevelop under Windows NT/2000/XP, Solaris, IRIX, or Tru64 UNIX/ DIGITAL UNIX, you just have to **restart** the program. HDevelop automatically integrates all extension packages specified in HALCONEXTENSIONS, i.e., the operators contained in a package can be accessed and used like any other HALCON operator.

Under Linux, you have to include the package library subdirectory lib/i586-linux2.2 (or lib/i586-linux2.2-gcc32 if you are using gcc 3.2/3.3) in the environment variable LD_LIBRARY_PATH before starting HDevelop the first time.

2.5.3 Using an Extension Package in a Stand-Alone Application

If you want to generate a stand-alone application using the package you have to link package libraries (DLLs under Windows, shared libraries under UNIX) to the application code (besides the standard HALCON library, of course).

2.5.3.1 Using an Extension Package Under Windows NT/2000/XP

In order to create new application programs (written in C or C++) you have to link packagec.lib or packagecpp.lib to your objects. Furthermore, you will need halconc.lib or halconcpp.lib (as for any HALCON application).

To be able to link the package DLL to your application program, the *complete* DLL file path of the new package, e.g.,

```
%HALCONROOT%\packages\halconuser\bin\i586-nt4
```

has to be added to the environment variable PATH.

Do not copy a package DLL into the Windows system directories, as it would be loaded twice in this case!

2.5.3.2 Using an Extension Package Under Linux

In order to create new application programs (written in C or C++) you have to link `libpackage.so` and `libpackagec.so` or `libpackagecpp.so` to your objects (besides `libhalcon.so` and `libhalconc.so` or `libhalconcpp.so` as for any HALCON application).

Furthermore, you have to add the package library subdirectory `lib/i586-linux2.2` (or `lib/i586-linux2.2-gcc32` if you are using `gcc 3.2/3.3`) to the environment variable `LD_LIBRARY_PATH`, otherwise the loader will fail to access the libraries.

2.5.3.3 Using an Extension Package Under Solaris

In order to create new application programs (written in C or C++) you have to link `libpackage.so` and `libpackagec.so` or `libpackagecpp.so` to your objects (besides `libhalcon.so` and `libhalconc.so` or `libhalconcpp.so` as for any HALCON application).

Furthermore, you have to add the package library subdirectory `lib/sparc-sun-solaris7` to the environment variable `LD_LIBRARY_PATH`, otherwise the loader will fail to access the libraries.

2.5.3.4 Using an Extension Package Under IRIX

In order to create new application programs (written in C or C++) you have to link `libpackage.so` and `libpackagec.so` or `libpackagecpp.so` to your objects (besides `libhalcon.so` and `libhalconc.so` or `libhalconcpp.so` as for any HALCON application).

Furthermore, you have to add the package library subdirectory `lib/mips-sgi-irix6.5` to the environment variable `LD_LIBRARY_PATH`, otherwise the loader will fail to access the libraries.

2.5.3.5 Using an Extension Package Under Tru64 UNIX (DIGITAL UNIX)

In order to create new application programs (written in C or C++) you have to link `libpackage.so` and `libpackagec.so` or `libpackagecpp.so` to your objects (besides `libhalcon.so` and `libhalconc.so` or `libhalconcpp.so` as for any HALCON application).

Furthermore, you have to add the package library subdirectory `lib/alpha-compaq-osf5.1` to the environment variable `LD_LIBRARY_PATH`, otherwise the loader will fail to access the libraries.

Chapter 3

A First Look at HDevelop

In this chapter you will learn how to solve an image analysis problem from the scratch. During an example session, the most important features of HDevelop are going to be introduced. You will become familiar with HDevelop's *graphical user interface (GUI)* and learn to use it efficiently.

The example is chosen from the domain of quality control. The goal is to detect all *ball bondings* on a *die*, see figure 3.1. The HDevelop program corresponding to the example session is included in the HALCON package subdirectory:

```
%HALCONROOT%\examples\hdevelop\Manuals\GettingStarted\example.dev
```

In particular it will be shown

- how to construct a HDevelop program with HALCON operators,
- how to find suitable operators and parameter values,
- how to handle iconic and control variables,
- how to handle the graphics window,
- how to generate a region of interest (ROI),
- how to solve the example problem using morphology,
- how to solve the example problem by pattern matching, and
- how to use control constructs.

Read this chapter very carefully and you will understand the basic interactive features of HDevelop. This will help you to develop your own sophisticated image analysis programs in the future.

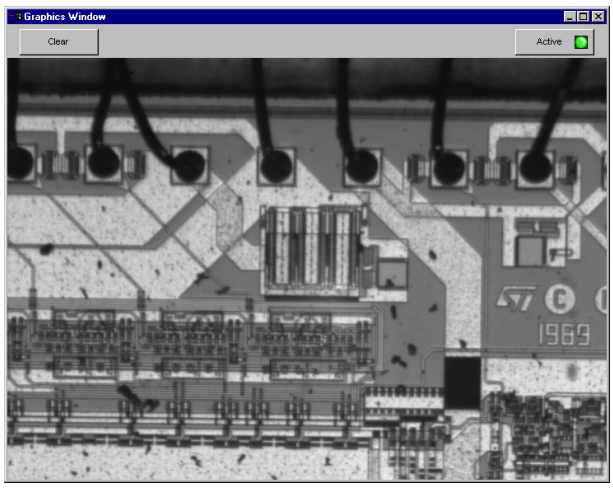

Figure 3.1: The image to be analyzed: All *ball bondings* on a die have to be detected.

3.1 The Graphical User Interface of HDevelop

You start HDevelop under Windows NT/2000/XP by calling

`Start ▷ Programs ▷ MVTec HALCON ▷ HDevelop`

Under UNIX, HDevelop is started from the shell by calling

```
hdevelop
```

Having started HDevelop, the *main window* will appear on your screen. It contains four[1] windows (see figure 3.2)

- a program window,
- an operator window,
- a variable window, and
- a graphics window.

In the following, the HDevelop windows will be explained briefly. For more details see the HDevelop User's Manual.

3.1.1 Main window

The *main window* is the central window and the starting point for your work. It comprises the creation of a HDevelop program (operator selection, editing, etc.) and the session management (loading, saving, etc.). This main window is identified by the title 'HDevelop' in the window's title bar. It also contains a *menu bar* and a *tool bar*.

[1] Please note that in the UNIX environment the main window, the program window, and the operator window are combined into one window. Thus, there are only *three* windows.

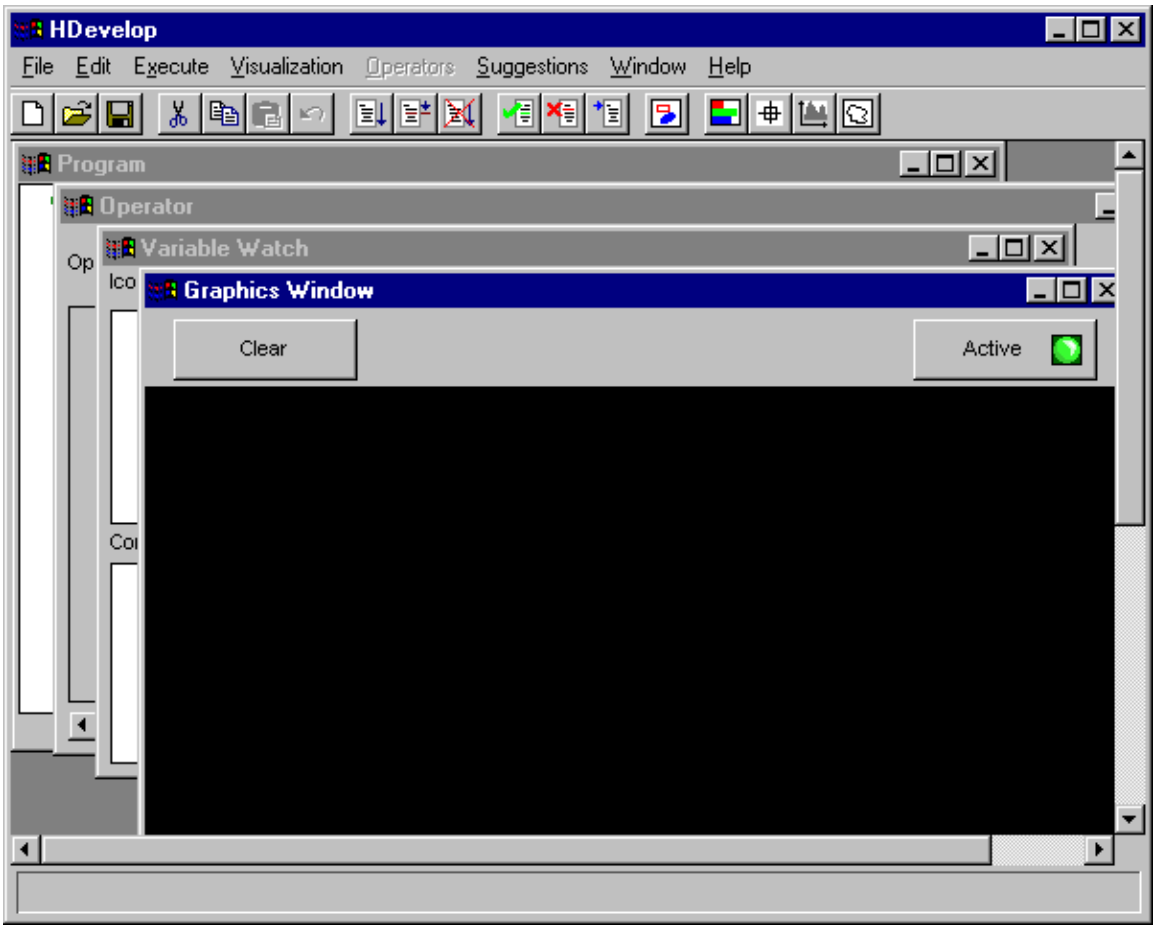

Figure 3.2: *The main window.*

- *Main window menus*
  In these menus you will find the complete HDevelop functionality, which is summarized in the following table. For more detailed information see the HDevelop User's Manual.

Menu	Contains Commands for:
File	Loading and saving of HDevelop programs and exiting HDevelop
Edit	Editing a HDevelop program
Execute	Running a HDevelop program
Visualization	Customizing the graphics windows and handling their output behaviour
Operators	Submenus containing programming constructs, HDevelop operators, and all HALCON operators
Suggestions	Support choosing an operator
Window	Window management
Help	Opening online documentation and guides

- *Main window tool bar*
  This tool bar offers shortcuts for frequently used commands. Furthermore, it provides the means to control the execution of an HDevelop program.

Button	Performs this Operation:
New	Deletes the current program in the program window
Open	Opens a new HDevelop program
Save	Saves a HDevelop program
Cut	Deletes program lines selected in the program window
Copy	Copies program lines selected in the program window
Paste	Inserts copied lines in the program window
Run	Executes the HDevelop program
Step	Executes the next command of the HDevelop program
Stop	Stops the running HDevelop program
Activate	Activates the lines selected in the program
Deactivate	Deactivates the lines selected in the program
Reset	Resets the program into its initial state and clears all variables
Set parameters	Opens the visualization parameter dialog window
Gray value inspection	Opens the window for gray value inspection
Zooming	Opens the online zooming window
Gray value histogram	Opens the interactive gray value histogram
Feature histogram	Opens the interactive region/XLD feature histogram
Region inspection	Opens the interactive region feature inspection window

3.1.2 Program Window

This window is used to display a HDevelop program. This might be an entire program, which has been loaded, or single operators only. It has two parts: The left area contains marks which control the running of a HDevelop program. In the initial HDevelop state you will see the *program counter* (*PC*), represented by a green arrow, and the *insertion cursor*, represented by a ▷. Additionally you may set a *break point* during program debugging (see the user HDevelop User's Manual for a detailed explanation). The right area contains the program code. It is empty in the initial state.

3.1.3 Operator Window

This window will show you important information about a chosen operator. It indicates all parameter names, their types, and their values. It supports you in specifying a parameter value by displaying a default value and alternative values. Additionally, you may get online help for each operator.

Another window element is the text field. If you are not quite sure about an operator name you may specify a substring in this text field. In this case, the system is going to search for all operators in its operator base which include this substring. They are displayed in a *combo box*, where you may choose the appropriate operator.

3.1.4 Variable Window

This is the control unit for variables generated during the execution of the program. Double-click on a variable to display its value. If the variable corresponds to an image or a set of regions (*iconic variable*), the contained objects are displayed in the Graphics Window.

3.1.5 Graphics Window

This window is used to display iconic variables. The visualization modes can be adapted to your needs with the functions provided in the `Visualization` menu. You may open an arbitrary number of graphics windows. Each window can be activated interactively or accessed using its specific window ID.

3.2 Editing a HDevelop Program

After starting HDevelop, the tool waits for your input. You create an application, in other words, write your HDevelop program, by adding lines in the Program Window. To add a new line,[2] i.e., a new operator, you have to perform two steps:

- Position the *insertion cursor* ▷ on the appropriate line of the program where you would like to insert the new line. This cursor is placed by pressing the `<Shift>` button on your keyboard and clicking in the left column beside of the program line with the left mouse button.
- Select the new operator using the `Operator` menu or type its name in the operator window's text field.

Now the new operator is displayed in the operator window. Provide or adapt the input parameters and — if desired — change the names of the output variables. Then click `Enter` to insert the operator as a new program line. If you click on `Ok` instead, the operator is not only inserted, but also executed immediately. Finally, if you click on `Apply` the operator is not inserted into the program, but only executed. This allows you to test the effect of your parameter settings very quickly and conveniently.

To execute an arbitrary line of a HALCON program you have to position the program counter (PC) at this line (just click at the left column beside the line). Then press the `Step` icon in the main window tool bar. If you press `Run` instead all subsequent lines will be executed until a breakpoint or a `stop` command is encountered. A single-click on a program line selects this line, a double-click transfers the line back to the operator window.

Once you have finished the program you can save it and load it again later, or you might export it as C, C++, or COM code to generate a standalone application (see `File` ▷ `Save as...`).

These basic steps will be used many times during the example session. So you will have many opportunities to get used to the different methods of editing program, specifying parameter values, etc. For now, just continue with applying your first operator to read an image.

3.3 Loading an Image

First of all, you have to create a HALCON object that contains your *input image*. You may obtain an image in several ways:

[2] The commands `Copy`, `Cut`, and `Paste`, which are also very convenient to edit a HDevelop program, will be explained later during this session.

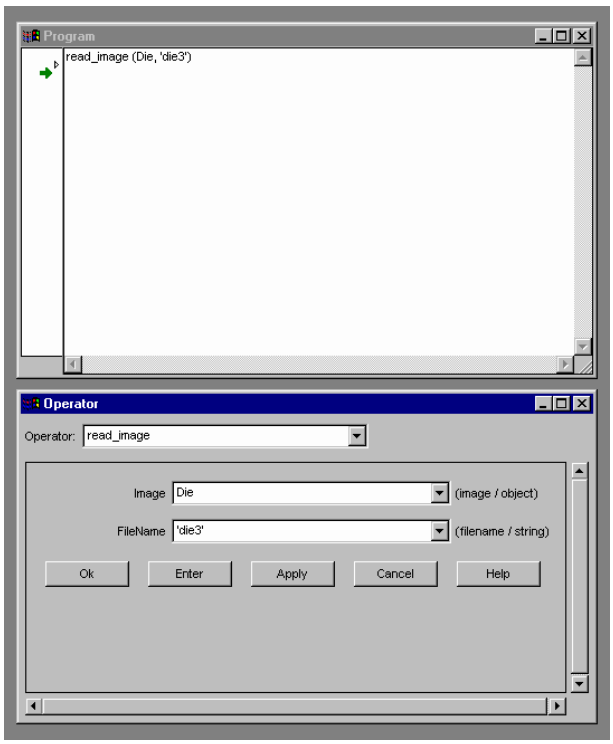

Figure 3.3: Setting the parameters of the operator `read_image`.

- You can use a frame grabber to obtain an online image (see menu item `Operators` ▷ `Image` ▷ `Framegrabber`).
- You can read an image from a file (see menu item `Operators` ▷ `File` ▷ `Images` and menu item `File` ▷ `Read image...`).
- You can create a new image (see menu item `Operators` ▷ `Image` ▷ `Creation`).

In the example we will use the `read_image` operator. Just select `read_image` in the submenu `Operators` ▷ `File` ▷ `Images` or type `read_image` in the operator window's text field and press `Enter`. Now the operator should be displayed in the operator window, see figure 3.3. The first parameter is the *image object* you are about to create. Change the default name of the corresponding variable to 'Die'. You get a text field focus by clicking the left mouse button inside the desired text field. The second parameter is the name of the image file. Change it to 'die3':

```
read_image (Die,'die3')
```

Having specified all parameters you should press `Ok` to transfer the operator to the *program window* and to execute it. Now you have created the first line of your program in the *program window*. The variable `Die` containing the image object you just created is displayed in the *variable window*. Simultaneously, the result of the operator (in this case the original image) is displayed in the *graphics window*. If you encounter an error trying to load the image, check whether your environment is set up correctly. The image should be located in `%HALCONROOT%\images` which is also the default search path for image files as long as you do not provide specific search paths in the `HALCONIMAGES` variable, see section 2.4.

3.4 Modifying the Graphics Window

The size of the initial graphics window is 512 × 512 pixels. If your image is bigger or smaller than this size it will therefore be displayed distortedly. You can interactively change the window size just by picking the lower right corner with the mouse, but the easiest way to see the undistorted image is to select `Visualization` ▷ `Size Window` ▷ `Original`. This enlarges or shrinks the window to the size of the most recently displayed image. However, in this example we are going to open a new window with the proper size because we will need its window handle later on. Again, there is a interactive way to do this (see menu `Visualization`), but we will use the HDevelop operator `dev_open_window` instead to include this task in the program itself. HDevelop operators are handled in the same way as HALCON operators. You can access them via the menu `Operators` ▷ `HDevelop` or directly via the *operator window's* text field. The parameter `Width` and `Height` specify the size of the window. If you do not know the size of the current image you just specify '-1' for both parameters. In that case the size of the most recently created image will be used.

```
dev_open_window (0,0,-1,-1,'black',WindowID)
```

Click on `Ok` and a new *graphics window* appears. It has the same size as your image. But the new graphics display remains dark. It is now the *active graphics window* and waits for your input. It is up to you what to display in this window. Double-click on the *iconic variable* `Die` in the *variable window* by using the left mouse button in order to display this image. Now you see the input image without distortion, see figure 3.1.

The default visualization for an image is to display the image matrix, i.e., the gray (or color) value of each pixel. You can easily switch to other visualization modes via `Visualization` ▷ `Set parameters...` ▷ `paint`. Choose for example '3D-plot' and select `Update` to see a 3D plot of the image. The various visualization modes are described in detail in the HDevelop Users Manual. Do not forget to change the mode back to 'default' before continuing with the example session. All the visualization modes can be modified within your program as well: For example, the display of the histogram is activated by `dev_set_paint('3D-plot')`. See also section 3.5 to learn how to manipulate the visualization of regions.

Furthermore, it is possible to zoom into the image. Just select the menu item `Visualization` ▷ `Set parameters...` ▷ `zoom`. Click on the upper `Interactive...` button. Now you can specify a rectangle within your graphics window. To do this you press the left mouse button to indicate the upper left corner. Keep the button pressed and drag the mouse to the lower right corner of the desired rectangle. Release the left button and click the right button once. Now you have specified the image part you are interested in. All visualizations are now zoomed to this image part. This is the interactive way to set an image part. Another possibility is the direct input of the coordinates of the image part (in `Visualization` ▷ `Set parameters...` ▷ `zoom` or to use the HDevelop operator `dev_set_part`). To visualize the whole image again, click `Reset` in `Visualization` ▷ `Set parameters...` ▷ `zoom`.

3.5 Creating a Region of Interest (ROI)

Very often it is useful to specify an ROI which is used in the following processing steps. By restricting the image domain the performance can be increased significantly because all following

image processing tasks will be performed only within this ROI and not on the whole image.

Figure 3.4: A rectangular and an arbitrary region of interest (ROI).

To generate a ROI you have the following possibilities:

- Interactive creation of a rectangular ROI:
  Select the operator `draw_rectangle1` from the menu `Operators` ▷ `Graphics` ▷ `Drawing` to draw a rectangle in the *graphics window*. Just execute the operator with the default names for the output variables (containing the pixel coordinates of the upper left and lower right corner of the rectangle). This creates a new line in the *program window* and HDevelop waits for you to draw the rectangle (like you did before while setting an image part to zoom in). After you finished the drawing, the four control output variables `Row1`, `Column1`, `Row2`, and `Column2` will appear in the *variable window*, see figure 3.5. To generate the corresponding ROI as an HALCON object, use the operator `gen_rectangle1` from the menu `Operator` ▷ `Regions` ▷ `Creation` with the variables `Row1` – `Column2` as input parameters. You might use 'ROI' as the name for the resulting output object:

```
draw_rectangle1 (WindowID, Row1, Column1, Row2, Column2)
gen_rectangle1  (ROI, Row1, Column1, Row2, Column2)
```

  By executing this operator you create another type of HALCON object — a region, see section 4.2.3.

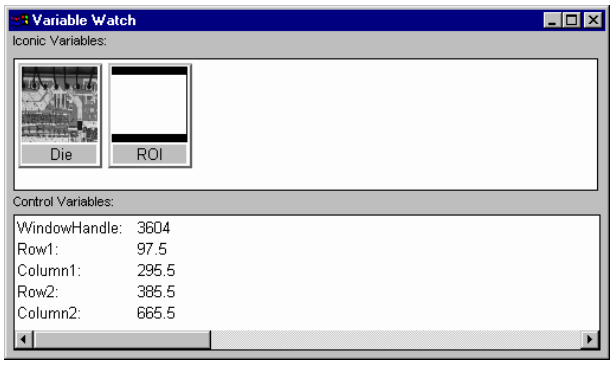

Figure 3.5: The variable window containing iconic and control variables.

The default visualization for a region is the shape of the region (here the rectangle) drawn with the current color into the *graphics window*. You may manipulate this graphics output by choosing items of the menu `Visualization` or executing the corresponding HDevelop operator `dev_*`. For example, set the drawing color to 'green' with `Visualization` ▷ `Color`, increase the line with for drawing to 3 pixels with `Visualization` ▷ `Line Width` and specify, that only the region boundary ('margin') instead of the whole region ('fill') should be displayed with `Visualization` ▷ `Draw`. Each time you change the visualization, the last iconic object that was drawn into the currently active graphics window is redisplayed (figure 3.4). Therefore, you need only redisplay an object by hand (by double-clicking it in the *variables window* if you want to change the display mode of an "older" object.

- Interactive creation of an arbitrary ROI:
  HALCON supports arbitrary regions as ROI, see figure 3.4. Just use `draw_region` from the menu `Operators` ▷ `Graphics` ▷ `Drawing` instead of the sequence `draw_rectangle1` and `gen_rectangle1`:

  ```
  draw_region (ROI, WindowID)
  ```

  To adapt the program in this way, you may select the line `draw_rectangle1` (just click on that line) and deactivate it with `Edit` ▷ `Deactivate`. Do the same with the line `gen_rectangle1`.

- Computation of a suitable ROI:
  The computation of a suitable ROI based on intermediate results of the image analysis is the most challenging but also the most flexible approach. In our example we will detect the board itself and use this as a ROI for the ball detection, see section 3.8.

Once you have generated a ROI you can reduce the image domain to this region with the operator `reduce_domain` from `Operators` ▷ `Image` ▷ `Domain`. Specify `Die` as input image and `ROI` as input region:

```
reduce_domain (Die, ROI, ImageReduced)
mean_image (ImageReduced, ImageMean, 11, 11)
```

The resulting image `ImageReduced` is only defined within the ROI. Clear the window and double-click on the variable `ImageReduced` to see this effect. You might apply a couple of operators to the original image and the reduced image to see the increase in performance. For example, try `mean_image` from `Operators` ▷ `Filter` ▷ `Smoothing` with `Die` as input image. Then clear the window and double-click on the `mean_image` program line to change the input image to `ImageReduced`.

To repeat the above sequence with different ROIs just place the `PC` on `draw_rectangle1` or `draw_region` (depending on which method you have activated) and press `Run`. In order to stop the execution of the program before a specific operator is applied, place a *break point* (BP) in the program line containing this operator (`Control` key and mouse click in the left column).

3.6 Finding the Right Operator

You have created your first HALCON object — the original image. But how to continue? There are about 1000 operators to choose from. Naturally, the selection of a suitable operator sequence depends on the image analysis task you have to solve. In general, it is up to your experience and image analysis knowledge to make the right selection. However, HDevelop supports you in many ways during this program development.

The HALCON operators are hierarchically structured. Just browse the `Operators` menu to get a first impression.

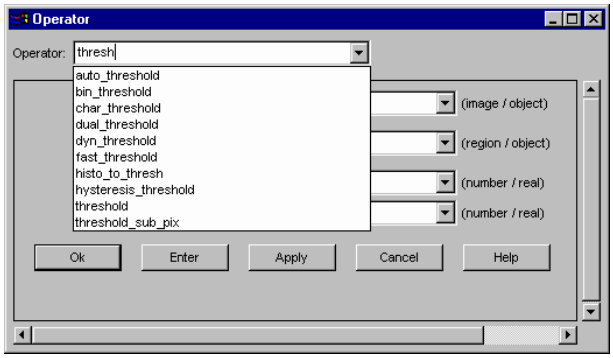

Figure 3.6: Selecting the `threshold` operator using the substring “thresh”.

Again, if you already know at least a substring of the operator name you might also just type this string in the *operator window*’s text field. If there is an ambiguity, you choose the operator inside the *combo box*, see figure 3.6.

For each HALCON operator HDevelop’s *online help* provides an HTML description. Just select `Help` ▷ `HTML...` to start your default browser. You will see the table of contents of all image analysis modules — structured in the same way as the `Operators` menu. Simply select an appropriate chapter and continue browsing until you find your operator. There are also many cross references according to the relationships between the operators. At the end of the main page there is an index of all operators, which helps you to jump directly to a specific operator HTML page.

Furthermore, the menu `Suggestions` ▷ `Keywords` offers access to HALCON operators by *keywords*. By selecting this menu item, a window is displayed with the available keywords on the left side and the operators related to the selected keywords on the right side. If you select a keyword using your mouse you will see the corresponding operators in the right area. Each mouse click in the left area marks the keyword and adds some operators in the right area. To finally select an operator and display it in the *operator window* just click on the operator name using your left mouse button.

Once you have selected one of the operators, like `read_image` in our example, you can enquire information related to this operator from the *operator knowledge base*:

- The HTML online help.
  Just click on the `Help` button to launch your default web browser and get the complete online documentation of the selected operator.

- Suggestions ▷ Alternatives
  If an intermediate result does not fulfill your requirements you might want to choose an alternative operator which might be more suitable for your task. Note, that in many situations there is a trade off between performance and accuracy of the results. For example, you might use the high performance smoothing filter mean_image in one situation and the higher quality smoothing filters gauss_image or smooth_image in another.

- Suggestions ▷ See also
  The online help of HDevelop also offers references to other operators, which are not exactly alternatives, but related to the current operator in some way. For example, if you currently look at read_image you might be interested in the write_image operator as well.

- Suggestions ▷ Predecessor
  Many operators require a specific input provided by other operators. For example, before computing junction points in a skeleton (junctions_skeleton), you have to compute the skeleton itself (skeleton).

- Suggestions ▷ Successor
  On the other hand, there are typical sequences of operators. Hence HDevelop suggests some reasonable operators to be executed following the operator you are currently looking at. For example, thresholding might be a good idea after applying an edge filter.

In our example you have just created the input image. Naturally, this is a very unspecific situation with lots of different opportunities to continue. However, we will accept one of the successor suggestions, the threshold operator later on.

3.7 Finding the Right Parameter Values

Once you have selected an operator (from the menu, by typing it's name, or by double-clicking on a program line in the program window), it is displayed in the *operator window*. Now you have to specify the parameters for the operator. Of course, you can type in every parameter manually (either a control value or a variable name). In many cases it is more convenient to use the *combo boxes* (click on the arrow at the right side of the parameter field) instead, which provide a listing of meaningful values or names of variables you specified within your program. Furthermore, for control input parameters default values are provided by HDevelop.

For example, apply a *threshold operator* to the input image by selecting the operator threshold from Operators ▷ Segmentation. Specify the input image Die using the *combo box*. If you use the default values for the lower and upper threshold, all pixels in the input image with *gray values* larger than 128 will be included in the resulting output region. Therefore, you could call the corresponding output variable BrightRegion. It might be helpful to set the visualization mode Visualization ▷ Draw to 'fill'. In this case you see all the selected image pixels painted in the current drawing color in the *graphics window*. Double-click on Die and BrightRegion again to underlay the visualization of the region with the original image, see figure 3.7.

To choose another parameter value just double-click on the program line containing the corresponding operator, change the parameter, and press Apply. The operator will be executed immediately and its result will be visualized. Repeat this process until you are satisfied with the

Figure 3.7: The region object `BrightRegion` containing all pixels with gray values larger or equal 128.

result, then press `Ok`. But remember to clear the window or underlay the original image before each new execution of an operator returning a region. Otherwise, you only see the accumulated visualization of all regions you generate during the parameter tuning.

3.8 Finding the Board as ROI

Looking at the input image `Die` you will notice that the surface of the board is quite bright. Thus, by applying the `threshold` operator with the default values 128 and 255, a reasonable *raw segmentation* of the board can be achieved. We will now transform this *raw segmentation* into a *region of interest* for the ball detection: Select the HALCON operator `shape_trans` with `BrightRegion` (the result of the thresholding) as input region and 'rectangle2' as value for the parameter 'type' to obtain the *smallest rectangle* (of arbitrary orientation) containing `BrightRegion`. The resulting region (called 'ROI') is a reasonable approximation of the board in the image. As in section 3.5, reduce the domain of the original image to this ROI with the `reduce_domain` operator:

```
threshold (Die, BrightRegion, 128, 255)
shape_trans (BrightRegion, ROI, 'rectangle2')
reduce_domain (Die, ROI, DieROI)
```

The following computations will be performed only on the resulting image `DieROI` within the board.

3.9 Finding Bonding Balls Using Morphology

If you look closer at your image you will notice that the bonding balls to detect are darker than the *die* itself. Therefore, another *thresholding* might be suitable as the next operation, see figure 3.8. Due to noise, the resulting region (all the dark parts within the board) might have

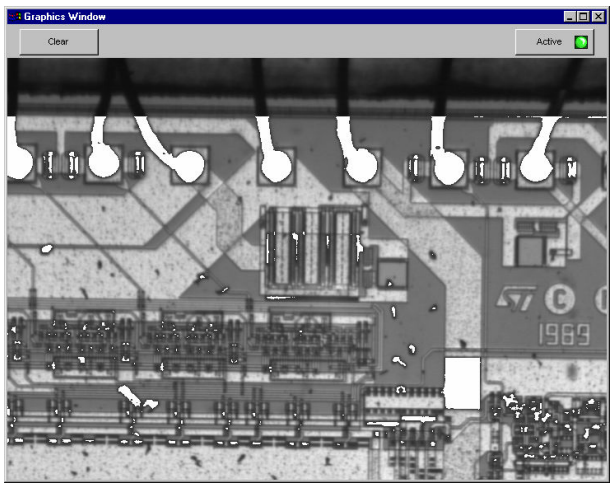

Figure 3.8: The region object `RawSegmentation` containing all dark pixels within the board.

some small holes which can obstruct further processing. For a controlled filling up of these artifacts, the HALCON operator `fill_up_shape` (in `Operators` ▷ `Regions` ▷ `Transformation`) is suitable.

```
threshold (DieROI, RawSegmentation, 0, 50)
fill_up_shape (RawSegmentation, Wires, 'area', 1, 100)
```

Visualize the variables `Wires` and `RawSegmentation`, then change the drawing color to see the difference.

Figure 3.9: Removing faulty parts of the raw segmentation with the `opening_circle` operation.

Unfortunately, the region found so far contains not only the bonding balls but also some darker areas, especially the wires connected to the balls. Obviously, the bonding balls have a circular shape. We use this information to separate the bonding balls from the other dark parts by using the HALCON operator `opening_circle` (in `Operators` ▷ `Morphology` ▷ `Region`). This morphological operation will suppress all parts of the region, where the underlying structural element — a circle with a specific radius — does not fit within the region, see figure 3.9.

```
opening_circle (Wires, BallRegion, 15.5)
```

Visualize the variables Wires and BallRegion, then change the drawing color to see the effect of this operation.

Now there is only one artifact left in the segmentation: A large dark rectangular shape, in which the circular mask for the opening has fitted as well. In order to eliminate this error the intermediate result — the region BallRegion — is separated into connected regions via the HALCON operator connection:

```
connection (BallRegion, Balls)
```

Note the difference: BallRegion is one region containing all the pixels of the segmentation so far. The different parts of this region are not connected, but still they form a single region. Balls is a variable containing seven separated HALCON objects — one per connected region. Set Visualization ▷ Colored to 12. Now 12 different colors are used cyclically to paint the region objects. It is a very convenient feature of the HALCON system that iconic variables can contain not only single objects, but also tuples of objects. Most HALCON operators accept such tuples as input and perform their task simultanously on all the contained objects. Due to this mechanism you won't have to program loops to process objects one by one in most situations.

Based on the circular shape of balls, the elimination of the rectangular region is now very simple. Just apply the select_shape operator (in Operators ▷ Regions ▷ Features) with 'circularity' as the selection criterion:

```
select_shape (Balls, FinalBalls, 'circularity', 'and', 0.85, 1.0)
```

Double-click on the variable Die, then on FinalBalls to see the selected regions only. Note again that Balls contains seven objects, from which you select all circular regions with this single operator call. Now, the ball segmentation is finished. In the next section it will be shown how to perform measurements based on the segmentation result. But before continuing, recall how simple it was to detect the balls and handle all the intermediate iconic objects generated:

```
read_image (Die,'die3')
threshold (Die, BrightRegion, 128, 255)
shape_trans (BrightRegion, ROI, 'rectangle2')
reduce_domain (Die, ROI, DieROI)
threshold (DieROI, RawSegmentation, 0, 50)
fill_up_shape (RawSegmentation, Wires, 'area', 1, 100)
opening_circle (Wires, BallRegion, 15.5)
connection (BallRegion, Balls)
select_shape (Balls, FinalBalls, 'circularity', 'and', 0.85, 1.0)
```

3.10 Working with Control Variables

So far we have detected the ball bondings within the image. Based on this segmentation we can now perform some simple measurements. The most obvious measurement is to count the balls

via count_obj (in Operators ▷ Object ▷ Information):

```
count_obj (FinalBalls, NumBalls)
```

Similiar to the draw_rectangle1 command in section 3.5 you generated a new control variable called NumBalls containing the desired number of balls. There are many different HALCON operators computing specific features of regions (see Operators ▷ Regions ▷ Features). Among them, one you might try now is smallest_circle. This operator determines the position and radius of the smallest circle containing each input region:

```
smallest_circle (FinalBalls, Row, Column, Radius)
```

Note that FinalBalls contains six objects. Thus, six circles are calculated — one for each of the input regions. Therefore, the output control variables Row, Column, and Radius do not contain single values, but tuples of values. Again, no loop construct is necessary to process all objects. Tuples of control values are shown in brackets within the variable window. If a tuple variable contains too many elements to be shown at once, the value list is truncated and three dots are added. For inspecting such a tuple, just double-click on the variable you want to see with the left mouse button. A window will be opened containing all the elements of the tuple.

Figure 3.10: The final result of the ball detection based on morphology.

The further processing of control data is facilitated by a built-in formula interpreter. See the HDevelop User's Manual for details. For example, you could compute the average value of the tuple Radius with the following HDevelop assign statement (see Operator ▷ Control)

```
assign (meanRadius, sum(Radius) / |Radius|)
```

which is displayed in the program window as

```
meanRadius := sum(Radius) / |Radius|
```

A more reasonable measurement concerning the quality control task might be the computation of the minimum area of the balls. This can be achieved by applying the HALCON operator

area_center (in Operators ▷ Regions ▷ Features), which calculates the area of each ball, followed by another assign statement:

```
area_center (FinalBalls, Area, RowCenter, ColCenter)
minArea := min(Area)
```

Of course, tuples of control values can also be used as input parameters. For example, draw the circles you have computed with the HALCON operator disp_circle (in Operators ▷ Graphics ▷ Output), see figure 3.10:

```
disp_circle (WindowID, Row, Column, Radius)
```

3.11 Finding Bonding Balls Using Pattern Matching

The morphologic approach detected the desired bonding balls by suppressing spurious parts of the raw segmentation gained by thresholding. In this section you will encounter a completely different approach to this detection problem. The pattern matching approach can be divided into two steps:

1. Creating a so-called *template*[3] (typically during a training phase).
2. Searching for this template in the current image.

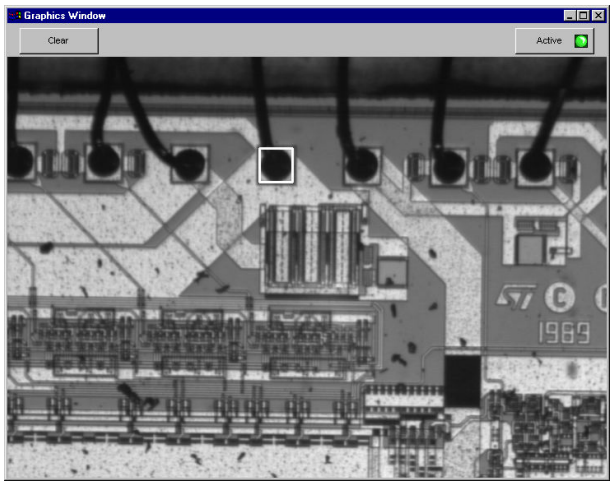

Figure 3.11: A template for a ball.

In our example we will create a template containing a single ball. To do this, just copy the two program lines you used to generate a rectangular search space (section 3.5):

```
draw_rectangle1 (WindowID, Row1, Column1, Row2, Column2)
gen_rectangle1  (ROI, Row1, Column1, Row2, Column2)
```

[3] another word for the pattern that is searched in the image

To do so, select the two program lines, copy them with Edit ▷ Copy, position the insertion cursor at the end of the program and select Edit ▷ Paste. Then, position the PC on the draw_rectangle1 command, press Run and draw a small rectangle containing nothing but one of the balls, see figure 3.11.

Then copy the program line for reducing the image domain to the resulting region ROI:

```
reduce_domain (Die, ROI, ImageReduced)
```

Now you can transform ImageReduced, which is the original image restricted to the rectangular domain you just have specified, to a template. This done by the HALCON operator create_template (in Operators ▷ Filter ▷ Match):

```
create_template (ImageReduced, 5, 4, 'sort', 'original', TemplateID)
```

To obtain the center of the template (which will be needed for visualization purposes later) use the following assign statements:

```
TemplRow := (Row1 + Row2)/2
TemplCol := (Col1 + Col2)/2
```

After the creation of the template you have the choice between different matching algorithms. We will use a two-step strategy. First, a fast matching operator is applied to find all image points where the template might match. In the second step, within each cluster of such points the exact position of the template will be determined. The HALCON operator fast_match (again in Operator ▷ Filter ▷ Match) delivers the region Matches containing all possible matching positions:

```
fast_match (Die, Matches, TemplateID, 20)
```

Double-click on the original image Die and the result region Match to see these positions. The input parameter MaxError is set to 20 in this example. There is a trade-off between performance and fault tolerance of the matching. Decrease the value and watch the execution time when applying the operator. For very small values of the tolerated error some of the balls might be missed. On the other hand, increasing the value decreases the performance significantly.

Besides fast_match there is also a HALCON operator fast_match_mg working on different resolution levels, which in general increases the performance. Just try

```
fast_match_mg (Die, Matches, TemplateID, 20, 3)
```

to perform a search with three resolution levels and compare the execution time with the one resolution method underlying fast_match.

After we have derived all posible matching positions, we decompose the corresponding region into connected components:

```
connection (Matches, BallROI)
```

If you specified a reasonable template and a suitable MaxError this should result in six regions corresponding to the six (fully) visible balls in the image.

```
count_obj (BallROI, NumBalls)
```

Within each of the regions in BallROI we would like to determine the exact position of the template. This can be done by another HALCON operator, called best_match.[4] BallROI contains only regions. Thus, we have to add an image, that is gray values, to the objects prior to the final matching. This is done with the operator add_channels (in Operators ▷ Image ▷ Channel):

```
add_channels (BallROI, Die, BallImage)
best_match (BallImage, TemplateID, 20, 'true', Row, Column, Error)
```

Note that the best_match operator is applied to all objects contained in BallImage. Thus, the control output variables Row and Column specifying the exact matching position and Error containing the matching error should be tuples of values. To visualize the results we display rectangles like the one used for the template generation — shifted by the offset beween the matching positions and the center of the template, see figure 3.12.

```
disp_rectangle1 (WindowID, Row1+Row-TemplRow, Column1+Column-TemplCol,
                           Row2+Row-TemplRow, Column2+Column-TemplCol)
```

You should make sure that the region visualization is set to 'margin' using Visualization ▷ draw before executing this command.

Figure 3.12: The final result of the ball detection based on pattern matching.

If you do not need the template any longer, it should be cleared with the HALCON operator clear_template. Summarizing, the ball detection using pattern matching was done by the following sequence of HALCON operators:

[4] Again, there is a multi-grid version of this matching operator, but since we already restricted the search to a very small part of the image, it is not too interesting to use best_match_mg in this case.

```
read_image (Die,'die3')
draw_rectangle1 (WindowID, Row1, Column1, Row2, Column2)
gen_rectangle1  (ROI, Row1, Column1, Row2, Column2)
reduce_domain (Die, ROI, ImageReduced)
create_template (ImageReduced, 5, 4, 'sort', 'original', TemplateID)
fast_match_mg (Die, Matches, TemplateID, 20, 3)
connection (Matches, BallROI)
add_channels (BallROI, Die, BallImage)
best_match (BallImage, TemplateID, 20, 'true', Row, Column, Error)
clear_template (TemplateID)
```

Note that the check for correct shape and area of each ball is implicitly done by the pattern matching. In the previous approach this was performed by the `opening_circle` operator.

By the way: Program lines that are not needed any more can be permanently removed. Just select them (left mouse button) and choose `Edit` ▷ `Delete`. Don't be shy — there is an `Edit` ▷ `Undo` as well. To temporarily deactivate a line use `Edit` ▷ `Deactivate` and `Edit` ▷ `Activate` to activate the line again.

3.12 Using Control Constructs

HDevelop offers various control statements to construct more complicated programs. For a detailed specification see the HDevelop Users Manual. You already have encountered the `assign` statement in the previous sections. We will now use two other control statements — `for` and `if` — to further improve the example program.

Up to now, all matching positions returned by `best_match` in section 3.11 were used to display a rectangle. This might lead to undesirable results if the matching fails for some of the input objects. Just decrease `MaxError` to 5, for example, to see what happens: For each input object in `BallImage` which does not contain the template 0 is returned in `Row` and `Column`[5] and the maximum average gray value deviation of 255 is returned in `Error`.

The correct way to handle these matching errors is to check for all resulting matching positions whether they are valid or not. Simultanously, the real number of detected balls can be computed: Initialize a counter with the `assign` statement

```
RealNumBalls := 0
```

Then program a loop with the counter `i` and the end value `NumBalls` (control statement `for`). Inside the loop, check the error value of each match and skip faulty matches:

```
for i := 1 to NumBalls by 1
   if (Error[i-1] < 255)
      disp_rectangle1 (Row1+Row[i-1]-TemplRow, Column1+Column[i-1]-TemplCol,
                       Row2+Row[i-1]-TemplRow, Column2+Column[i-1]-TemplCol)
      RealNumBalls := RealNumBalls + 1
   endif
endfor
```

Display the original image `Die` again and execute the above loop to see the result.

[5] A template position which is actually outside of the current image, because `Row` and `Column` specify the position of the *center* of the template.

Chapter 4

Philosophy of HALCON

This chapter explains the basic concepts of the HALCON system: its modular architecture and its data structures. Furthermore, it describes HALCON's frame grabber interface.

4.1 Modular Structure

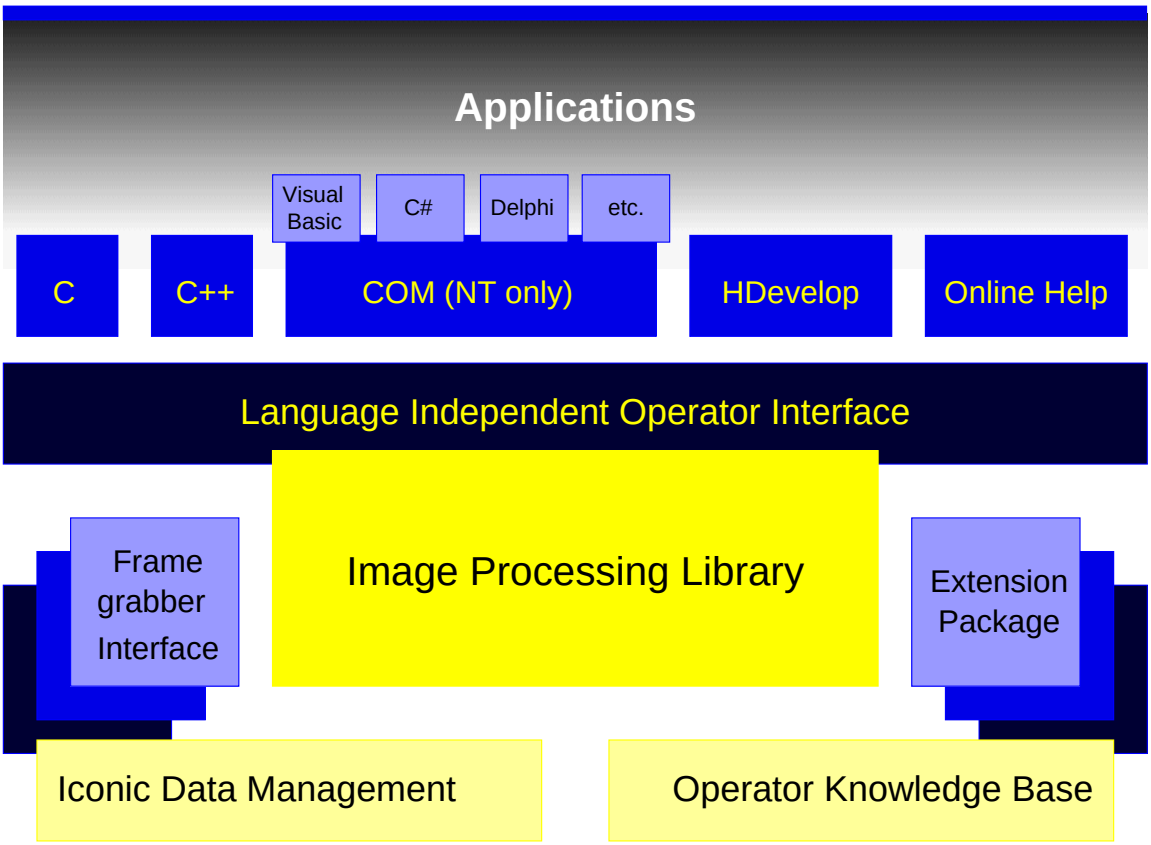

Figure 4.1: *Layered structure of HALCON .*

The base of HALCON is the *data management* together with the *operator knowledge base*. The data management is reponsible for basic memory management (optimized for image processing)

and on top of this for the creation, handling, and deletion of iconic objects and tuples. The knowledge base stores information about operators, which can be accessed while the system is running. All other modules make use of it to process image operations and to obtain information about the configuration and current state of the system.

The knowledge base is also used to *automatically* generate the HALCON language interfaces (for C, C++, and COM), all operator information used by HDevelop, the online help, and the reference manuals. The operator knowledge base contains information about names and number of operators, as well as parameter types, assertions and suggested values for the parameters. This data set is stored in a structured way. There exists a detailed description for each operator which handles the effects of the operator and which indicates the complexity, the operator class, as well as cross references and alternatives.

On top of these two modules the operators are implemented. Most of them are contained in the HALCON*Image Processing Library* (operator library), which is decribed in the Reference Manuals. This library can be extended dynamically using so-called *extension packages*. The operators of these packages behave like normal HALCON operators, but they contain extensions to the standard library either generated by MVTec (for easy update) or by the user. This concept permits the user to extend the system in a very flexible way. For more information see the Extension Package Programmer's Manual . Using a similar mechanism, *frame grabber interfaces* are integrated using dynamic libraries. This allows the user to integrate his/her own frame grabber or to download new releases of frame grabber interfaces via the internet for fast and easy update without further changes of the rest of the system.

The next module is the *Language-Independent Operator Interface*. It contains modules for calling operators, handling the input/output and passing data objects to the host language. An operator call is performed by the *Language Interface*, which is generated *automatically* by a compiler using the information in the operator database. There are three language interfaces: HALCON/C allows to access HALCON operators within the programming language C, HALCON/C++ within C++, and HALCON/COM (Windows NT/2000/XP only) within programming languages or environments that support COM, e.g., Microsoft Visual Basic , C#, or Borland Delphi. Note that you can also use HALCON/COM within Visual C++ programs, but then you cannot use HALCON/C++ in the same program, because only one HALCON language interface can be used in a single application, be it directly or indirectly, e.g., by including a DLL that uses a second interface.

HDevelop is implemented on top of the language interface using the language interface HALCON/C and the GUI toolkit **wxWindows** developed by the *Artificial Intelligence Applications Institute* at *The University of Edinburgh* to get a portable user interface for Windows and UNIX.

4.2 Handling Iconic and Control Data

HALCON distinguishes two types of data: *iconic data* and *control data*. *Iconic* data is related to the original image (images, regions, XLD objects; see below). *Control* data are all kinds of "numerical" values, such as integers, floating-point numbers, or strings; this kind of data defines input values for operator control parameters and is used to build complex structures like bar charts or arrays of control values. Both — *iconic* and *control* data — are processed according to the "tuple scheme" within HALCON.

4.2.1 Tuple Processing

Whenever an input or output parameter of a HALCON operator contains data, it may be a single object/value or a *tuple* of objects/values. If a tuple is passed HALCON processes the operator simultaneously on all tuple members. For example, if you want to process a median filter on six different images, you might call the operator `median_image` six times with varying input images. Or you might generate a tuple containing all six images and call `median_image` once with the tuple as input object. HALCON filters all tuple elements simultaneously and returns a tuple containing six filtered images. We have seen another example before in chapter 3, where several regions have been extracted from an input image. The regions became elements of one region tuple. If you want to know the center of all regions, you simply have to pass this tuple to the operator `area_center`. HALCON then returns a tuple of integer pairs containing the pixel positions of all centers.

Now that we know how tuples are processed we can have a closer look at the different object classes of iconic data: images, regions, and XLD objects.

4.2.2 Image Objects

Image objects contain the pixel data for image processing. They may be tuple objects containing more than one image object or a single image object. Every single image object consists of one *domain* describing its area of definition and one or more *channels* containing the gray values of the pixels (cf. figure 4.2). The number of channels is not restricted. A monochrome image may only have one channel, a color image may contain three channels according, e.g., to the RGB scheme, a multisensor image may have several channels.

The domain of an image object may be of any size and is represented by a *region*. Thus, it can have holes or may consist of several, unconnected areas (see figure 4.3). The default domain of an image object is the smallest rectangle enclosing the image. It may be changed to any size, e.g., via the operator `reduce_domain`, so that every image has its individual domain.

Introducing an area of definition for an image has the following advantage: All image operators work only within this image domain. This allows to focus the processing on a *region of interest*. The amount of data to work on becomes smaller so that the processing is sped up. An example that explicitly makes use of this can be found as HDevelop program named `autobahn.dev` under the path `%HALCONROOT%\examples\hdevelop\Applications\Sequences`.

4.2.3 Region Objects

Regions define areas in images, e.g., the domain of an image or the light areas of an image. Region objects consist of one or more regions. They are handled as separate objects independent from any image object, although they may represent an area within a specific image. This allows to use flexible shapes and sizes for regions and to store them efficiently. Only the region area must be represented in memory — independent from the gray values of the pixels. Moreover, this allows to define overlapping regions for the same image without the implicit merging that would happen when storing regions as matrices.

Region data is represented by a special variant of the runlength encoding — by a *chord encoding*: for every line (chord) of a region, its row index (y-coordinate of chord; “line number”) and

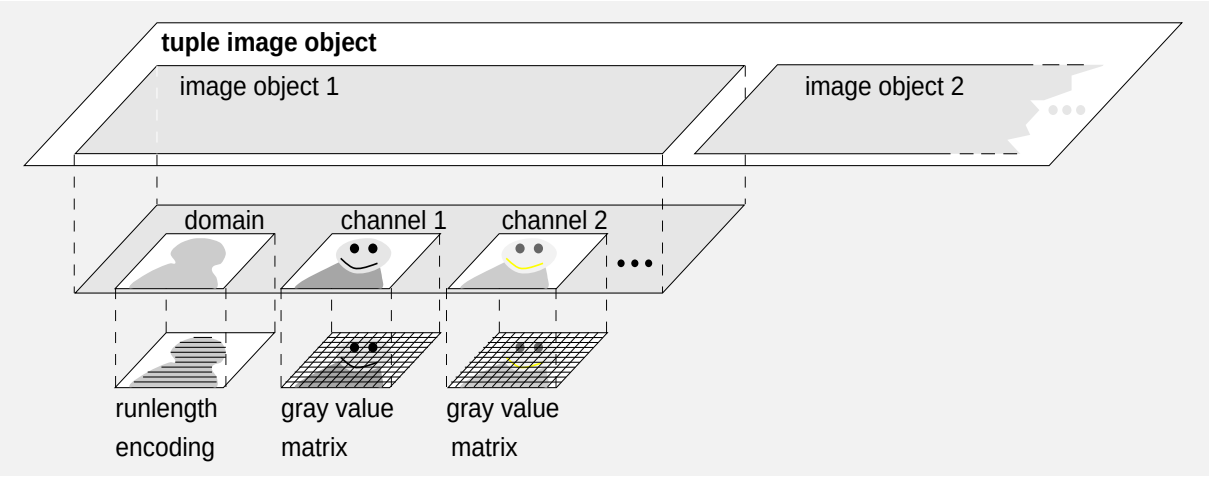

Figure 4.2: Structure of HALCON image objects.

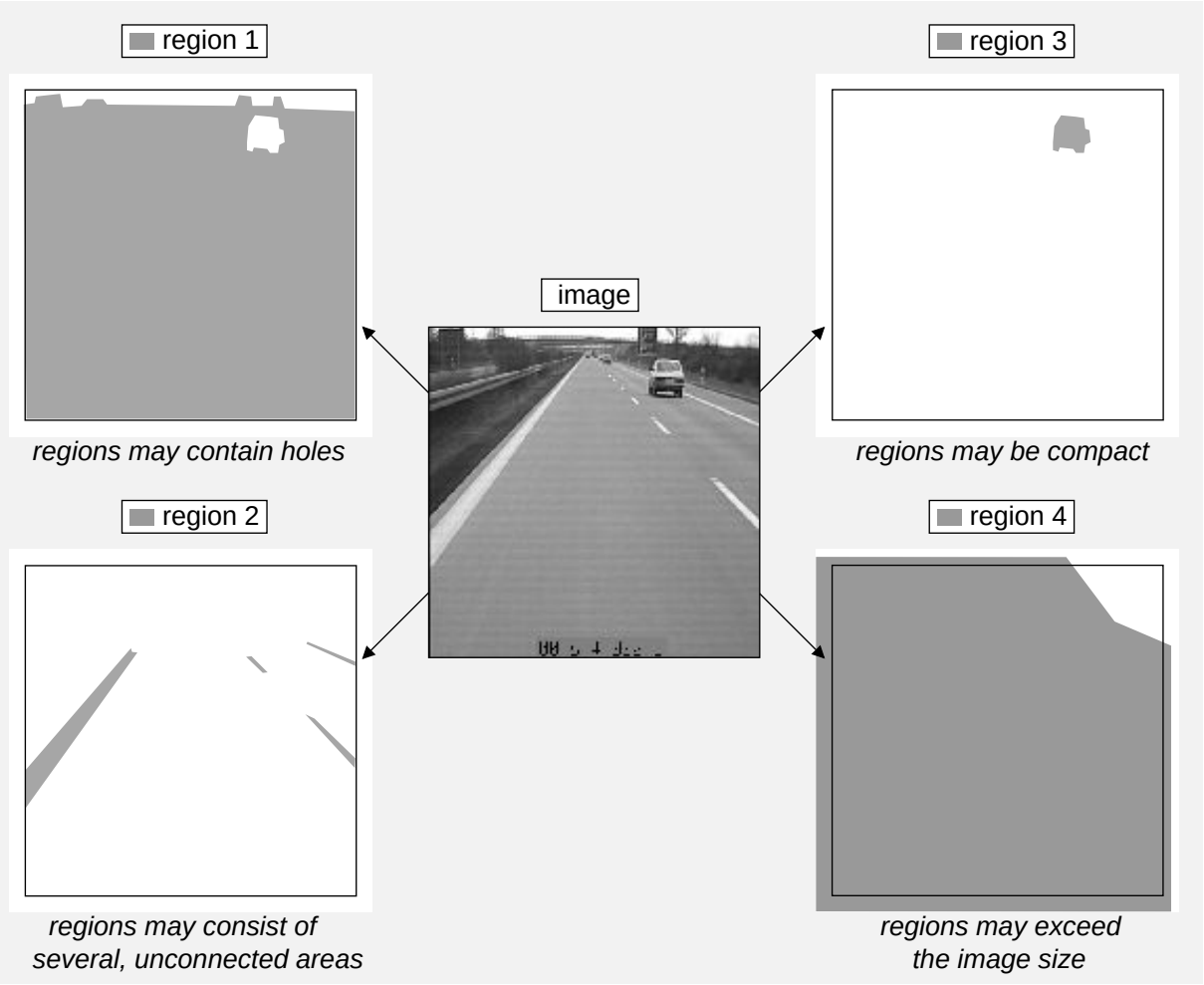

Figure 4.3: Different forms and sizes of regions.

the x-coordinates of its start- and end-point is stored. Both — the start-point and the end-point — belong to the region. This allows a very compact representation of regions in memory and an efficient region processing, especially with morpholgic operations.

Regions may be of any size and therefore even may exceed the image size. This is an additional advantage, since it prevents artifacts. For example, imagine you want to close a region with a circular structuring element to smooth the region's boundaries and to close holes within the region, e.g., via the operator `closing_circle`. You use this to extract a little fin (see figure 4.4 or cf. the HDevelop program example `fin2.dev` under the path `%HALCONROOT%\examples\hdevelop\Applications\FA`). The closing is done by a dilation followed by an erosion, both with the same circular structuring element — in our case a circle of radius 250 (you may think that 250 is rather large, but with the advanced performance of HALCON this causes no performance problem). Now imagine that the maximum region size would be restricted to the image size. Thus after processing the first step (the dilation) the resulting region has to be clipped to the image size (see figure 4.4.a). The following erosion would work on a restricted area and therefore result in a much smaller area than the correct processing (see figure 4.4.b). This would make the correct extraction of the fin impossible.

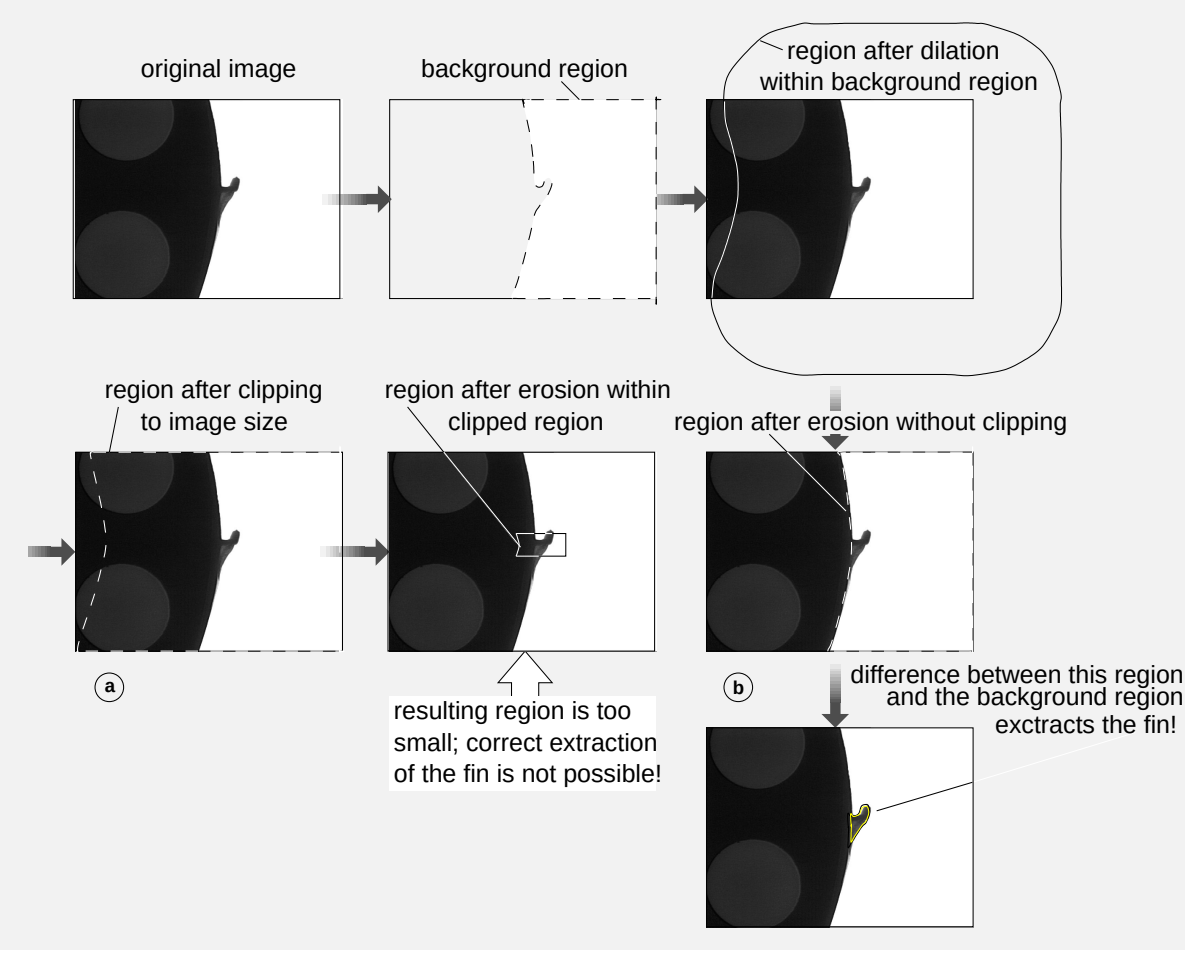

Figure 4.4: Example of region processing.

4.2.4 XLD Objects

XLD is the abbreviation for e**X**tended **L**ine **D**escription. This is a data structure used for describing areas (e.g., arbitrarily sized regions or polygons) or any closed or open contour, i.e., also lines. In contrast to regions, which represent all areas at pixel precision, XLD objects provide subpixel precision. There are two basic XLD structures: contours and polygons.

An XLD object is built up by setting base points along the contour/lines and connecting them with lines. They can represent a contour (or set of lines) at any precision by varying the number and position of the base points at subpixel precision. Additional information, such as gradient, filter response, or angle is stored with the points and lines. Typically, XLD objects describe the result of operators for edge/line detection (e.g., `edges_sub_pix`, `lines_gauss`). In particular, they are used for image processing at subpixel precision and offer a wide range of features and transformations. See the Extension Package Programmer's Manual for internal details.

4.3 The HALCON Frame Grabber Interface

Currently, HALCON provides interfaces about 50 [1] frame grabbers, in form of *dynamically loadable libraries* (Windows: DLLs; UNIX: shared libraries). These libraries are installed together with the HALCON libraries (see section 2.1.4 for the file structure). Library names start with the prefix `HFG`; the libraries starting with `parHFG` are used by Parallel HALCON (see also section 5.3.2).

In the following, we give a brief overview of the HALCON frame grabber interface; please refer to the Application Note on Image Acquisition for detailed information about this topic.

The HALCON frame grabber interface libraries form the bridge between software provided by the frame grabber's manufacturer and HALCON. They form a common, generic interface by providing the following operators:

`open_framegrabber` opens and configures a specified frame grabber. Depending on the frame grabber, several parameters must be specified, e.g. describing the type of the used camera or the port the camera is connected to.

`info_framegrabber` returns information about a specified frame grabber, e.g., the default parameters used by `open_framegrabber`.

`set_framegrabber_param` and `get_framegrabber_param` allow to set or read additional parameters. Which parameters are supported by a HALCON frame grabber interface can be queried via the operator `info_framegrabber`.

`grab_image` and `grab_image_async` grab an image from a specified frame grabber. For the difference between the two modes of grabbing see below.

`grab_image_start` starts an asynchronous grabbing from the specified frame grabber (see below for more details).

`close_framegrabber` and `close_all_framegrabbers` close the connection to one or all frame grabbers and release the corresponding resources, e.g., free the previously allocated memory.

`set_framegrabber_lut` and `get_framegrabber_lut` allow to set or read a frame-grabber-specific lookup table. These operators are only supported by some frame grabbers.

[1] Please refer to `http://www.mvtec.com/halcon/framegrabber` for an up-to-date list.

If you successfully installed your frame grabber, all you need to do to access it from HALCON is to call the operator open_framegrabber, specifying the name of the frame grabber and some additional information, e.g., regarding the connected camera. Then, images can be grabbed by calling the operator grab_image (or grab_image_async, see below).

Please note, that the HALCON frame grabber interfaces may change more often than the HALCON library itself. One reason is that MVTec continuously develops new interfaces; furthermore, if the software provided by the frame grabber manufacturers changes, e.g., if new features are integrated, the corresponding HALCON interfaces will be adapted. You can find the latest information together with downloadable interfaces (including documentation) under `http://www.mvtec.com/halcon/framegrabber`.

4.3.1 The Two Modes of Grabbing Images

HALCON distinguishes two grabbing modes: synchronous and asynchronous grabbing. *Synchronous grabbing* means that the application tells the frame grabber to grab a new image by calling the operator grab_image, and waits until the image is ready. In other words, the application synchronizes itself with the grabbing process. The advantage of this mode is that grabbed images are always up to date. However, because the grabbing process can take quite a time to complete, e.g., $40ms$ with standard PAL, real-time image processing becomes difficult (if not impossible) using synchronous grabbing. Synchronous grabbing is even more problematic when using an external trigger (see the following section), as then the application will wait for the trigger.

The second mode, *asynchronous grabbing*, supports *real-time image processing*. In this mode, the grabbing process is divided into two steps: First, the application tells the frame grabber to start grabbing a new image by calling the operator grab_image_start. This operator immediately returns; thus, the application can continue with its own task, e.g., process the previous image while the frame grabber grabs a new image. To actually fetch the new image, the application calls the operator grab_image_async. If the frame grabber has already finished grabbing the image, grab_image_async returns directly with the image; otherwise the operator waits until the frame grabber has finished. Furthermore grab_image_async allows to specify "how old" the grabbed image is allowed to be. If the image is too old, grab_image_async automatically starts a new grab and waits for its completion. Before returning, the operator grab_image_async automatically starts a new grab; therefore, you do not need to call the operator grab_image_start anymore after the first grab.

Note, that asynchronous grabbing is the more powerful of the two modes, but requires a careful timing on the part of the user. In other words, image processing (application side) and grabbing process (frame grabber) can only run asynchronously if the operator grab_image_async is called when the image is already grabbed (and not too old already)!

4.3.2 Using External Triggers

Independent of the grabbing mode, you can use an *external trigger signal* to start the actual grabbing process in the camera (if the frame grabber supports this option) and thereby synchronize the image grabbing to a physical process, e.g., by using photoelectric barriers that report when a part has arrived for inspection. All you need to do to use this feature from HALCON is to specify a corresponding parameter in the call to open_framegrabber.

Please note the difference between the two ways of synchronizing described here and in the previous section: In the synchronous grabbing mode, your application software is synchronized with the process of image grabbing so that image processing starts directly after getting a new image. When using an external trigger, image grabbing is synchronized with an external process so that the grabbed image corresponds to a certain situation, e.g. with an object directly under the camera.

When using an external trigger signal, keep in mind that after being told to grab an image the frame grabber waits for this signal – possibly ad infinitum if this signal is not triggered! Together with the frame grabber, calls to the operator grab_image (and even grab_image_async, if called before the signal comes) have to wait.

Most HALCON frame grabber interfaces allow to specify a timeout for grabbing via the operator set_framegrabber_param. If a grab runs into a timeout, the corresponding operator returns the value H_ERR_FGTIMEOUT.

Please note, that in order to really synchronize the grabbing process with an external event, the camera must be able to start a new image immediately. This feature is typically called *asynchronously resettable*. If a camera does not have this feature, the frame grabber must wait for the camera to finish its current frame before starting to grab. This means that there will be a delay between the external trigger and the start of the grabbing. Even worse from the point of view of real-time applications, the exact duration of this delay is unknown, as it may lie between zero and the time needed for one frame.

Summarizing, in applications with hard real-time constraints external triggers should be used in conjunction with an asynchronously resetable camera and the asynchronous grabbing mode.

4.3.3 Volatile Image Grabbing

By default, the operators grab_image and grab_image_async copy the image data written by the frame grabber into a certain memory area into a HALCON image object. The advantage of this mode is that your application can process the returned image object as long as it likes without it being "overwritten" by a subsequent grab. Furthermore, the application can keep a history of images if necessary.

As copying costs processing time (typically about $2 - 3ms$ for a NTSC image) which might be precious in a real-time application, some HALCON frame grabber interfaces offer the so-called *volatile grabbing mode*. In this mode, the frame grabber directly writes the image data into a HALCON image object used by the application. Thus, no copying is required. The drawback of this mode is that older images will be overwritten by subsequent grabs[2], thus the name "volatile".

Whether a frame grabber interface supports volatile grabbing is noted in its online documentation.

[2] In fact, the HALCON frame grabber interfaces internally use a so-called *double buffering* strategy to assure that a HALCON application can process one image while the next image is grabbed. Then, buffers are switched so that with the third grab the first image is overwritten.

4.3.4 Using Frame Grabbers Without a HALCON Interface

If you use a frame grabber that is not yet supported by HALCON, you can integrate a corresponding interface into HALCON. How to create and integrate a frame grabber interface is described in the Frame Grabber Integration Programmer's Manual , which also contains sample source code.

If you already have a program that communicates with the API of your frame grabber and want to use HALCON to process the images, you can convert the images grabbed by your program to HALCON images by passing HALCON a pointer to the image buffer using the operator `gen_image1_extern`.

4.4 Limitations

There are some HALCON limitations which you have to keep in mind, although you won't come even near these limits in most applications:

- Maximum image size: 32767×32767
- Maximum number of image matrices in memory[3]: 100000
- Maximum number of objects per parameter: 100000
- Maximum number of channels per image: 1000
- Maximum number of values in a tuple: 1000000
- Maximum number of contour points: 30000
- Maximum number of polygon control points: 10000
- Range for coordinates: from -32768 to $+32767$
- Maximum length of strings: 1024 characters

[3] Not to be confused with image objects, since objects can share the underlying gray values.

Chapter 5

Using Parallel HALCON

This chapter explains how to use Parallel HALCON, concentrating on the main features of Parallel HALCON: automatic parallelization and the support of parallel programming.

Like standard HALCON, Parallel HALCON can be used in two ways: You can integrate the corresponding libraries in your own C++, C, or COM programs, or you can use the parallelized variant of HDevelop, Parallel HDevelop.

Parallel HALCON and HDevelop

Like the HALCON library, HDevelop exists in two variants: The standard HDevelop builds upon the standard HALCON library; as before the corresponding executable is called `hdevelop` (or `hdevelop.exe`). The second variant builds upon Parallel HALCON and therefore automatically parallelizes operators if used on a multi-processor hardware. The corresponding executable is called `parhdevelop` (or `parhdevelop.exe`); under Windows NT/2000/XP, you can start it via the menu `Start` ▷ `Programs` ▷ `MVTec HALCON` ▷ `Parallel HDevelop`.

Note, that Parallel HDevelop differs from standard HDevelop only insofar that it uses the automatic parallelization mechanism. You cannot write parallel programs inside Parallel HDevelop.

Parallel HALCON in a Stand-Alone Application

To create an application using Parallel HALCON, you must link the corresponding libraries to your programs. Under Windows NT/2000/XP, you need the libraries `parhalconc.dll`, `parhalconcpp.dll`, or `parhalconx.dll`, depending on the used programming language. Under UNIX, you need the library `libhalcon.so` and, depending on the used programming language, `libparhalconc.so` or `libparhalconcpp.so`. Please consult the HALCON/C User's Manual , the HALCON/C++ User's Manual , or the HALCON/COM User's Manual , respectively, for more detailed information.

5.1 Automatic Parallelization

If Parallel HALCON is used on multi-processor hardware, it will automatically parallelize image processing operators. Section 5.1.1 describes how to initialize Parallel HALCON in order to

use this mechanism. Section 5.1.2 explains the different methods which are used by HALCON operators for their automatic parallelization.

5.1.1 Initializing Parallel HALCON

In order to adapt the parallelization mechanism optimally to the actual hardware, Parallel HALCON needs to examine this hardware once. Afterwards, HALCON programs will be automatically parallelized without needing any further action on your part. Even existing HALCON programs will run and be parallelized without needing to be changed.

You trigger this initial examination by calling the operator `check_par_hw_potential` (see the corresponding entry in the HALCON Reference Manuals for further information). Note, that this operator will only work correctly if called from Parallel HALCON; if you call the standard HALCON version (e.g., from HDevelop instead of Parallel HDevelop), a corresponding error message is returned. Similarly, if you call the operator on a single-processor computer, it will return an error message. As a shortcut, you may call the executable `hcheck_parallel` which resides in the directory `%HALCONROOT%\bin\%ARCHITECTURE%`.

Upon calling `check_par_hw_potential`, Parallel HALCON examines every operator that can be sped up in principle by an automatic parallelization. Each examined operator is processed several times - both sequentially and in parallel - with a changing set of input parameter values, e.g., images. The latter helps to evaluate dependencies between an operator's input parameter characteristics (e.g. the size of an input image) and the efficiency of its parallel processing. This examination may take up to 10 minutes, depending on your computer.

The extracted information is stored in the registry (under Windows NT/2000/XP) or in the file `.halcon_par_info` in the directory `$HALCONROOT` (under UNIX). Please note, that on some operating systems you need special privileges to initialize Parallel HALCON successfully, otherwise the operator `check_par_hw_potential` is not able to store the extracted information. Under Windows 2000, you need administrator privileges or the group privileges `'Power User'`. Under UNIX, per default only the user who installed HALCON can create (or modify) the file `.halcon_par_info`. Please note, that the operator `check_par_hw_potential` returns without an error if it cannot store the extracted information. In contrast, the program `hcheck_parallel` checks privileges and writing permissions beforehand and returns with a corresponding error message.

5.1.2 The Three Methods of Automatic Parallelization

For the automatic parallelization of operators, Parallel HALCON exploits *data parallelism*, i.e., the property that parts of the input data of an operator can be processed independently of each other. Data parallelism can be found at three levels:

1. **tuple level**
   If an operator is called with iconic input parameters containing tuples, i.e., arrays of images, regions, or XLDs, it can be parallelized by distributing the tuple elements, i.e., the individual images, regions, or XLDs, on parallel threads. This method requires that *all input parameters* contain the *same number of tuple elements* (or contain a single iconic object or value).

2. **channel level**
   If an operator is called with input images containing multiple channels, it can be parallelized by distributing the channels on parallel threads. This method requires that *all input image objects* contain the *same number of channels* or a single channel image.

3. **domain level**
   Every operator can be parallelized by dividing its domain and distributing its parts on parallel threads.

The description of a HALCON operator in the Reference Manuals contains an entry called 'Parallelization Information', which specifies its behavior when using Parallel HALCON. This entry indicates whether the operator will be automatically parallelized by Parallel HALCON and by which method (tuple, channel, or domain).

5.2 Parallel Programming Using Parallel HALCON

Parallel HALCON supports parallel programming by being thread-safe and reentrant, i.e., different threads can call HALCON operators simultaneously without having to wait. However, not all operators are fully reentrant. This section takes a closer look at the reentrancy of Parallel HALCON. Furthermore, it points out issues that should be kept in mind when writing parallel programs that use Parallel HALCON.

The example program `example_multithreaded1.c` in the directory `example\c` shows how to use multithreading to extract different types of components on a board in parallel using Parallel HALCON/C.

5.2.1 A Closer Look at Reentrancy

In fact there are different "levels" of reentrancy for HALCON operators:

1. **reentrant**
   An operator is fully reentrant if it can be called by multiple threads simultaneously independent of the data it is called with.

2. **local**
   This level of reentrancy is only relevant under Windows NT/2000/XP.

   Under Windows NT/2000/XP, operators marked as *local* should be called only from the *main thread* (and not from an *external thread*). Typical examples are operators that use graphical I/O functions. The reason is that under Windows NT/2000/XP, there exists a direct mapping between program threads and graphical elements, such as windows, dialog boxes or button controls. In short, a graphical element only exists in the context of its associated thread. This can cause severe problems (for example, hang the application) if a thread tries to perform user interactions via graphical elements that belong to another thread. For example, you may get a deadlock if one thread opens a window via `open_window` and another thread tries to get input from this window via `draw_circle`.

   As it is not always obvious whether an operator works with critical (graphical) elements or not, such operators are marked as *local*. Note, that you can still use them outside the main thread, however, you might get problems.

3. **single write multiple read**
   A certain group of operators should be called simultaneously only if the different calling threads work on different data. For example, threads should not try to modify the same template for pattern matching simultaneously by calling `adapt_template` with the same handle. Exactly the same applies to the case that one thread should not modify a data set that is simultaneously read by another thread. Other groups of operators with this behavior are concerned with file I/O (e.g., `write_image` – `read_image`, `fwrite_string` – `fread_string` but also non-HALCON file commands) or background estimation (e.g., `update_bg_esti` – `give_bg_esti`).

   As this thread behavior is not recommended quite generally, Parallel HALCON does not actively prevent it and thus saves overhead. This means that if you (accidentally) call such operators simultaneously with the same data no thread will block, but you might get unwelcome effects.

4. **mutual exclusive**
   Some operators cannot be called simultaneously by multiple threads but may be executed in parallel to *other* HALCON operators. Examples for mutual exclusive operators are `combine_roads_xld`, `pouring`, or `concat_ocr_trainf`.

5. **completely exclusive**
   A group of operators is executed exclusively by Parallel HALCON, i.e., while such an operator is executed, all other threads cannot call another HALCON operator. Examples are all OCR/OCV operators that modify OCR classificators, all operators that create or delete files, and the operator `reset_obj_db`. For the latter, a programmer has to assure that all operators that are to be executed *before* `reset_obj_db` is called have already finished, because this operator resets HALCON and therefore strongly influences its behavior.

As mentioned already, the description of a HALCON operator in the Reference Manuals contains an entry called 'Parallelization Information', which specifies its behavior when using Parallel HALCON. This entry specifies the level of reentrancy as described above.

5.2.2 Style Guide

- **Initialization**
  Before calling HALCON operators in parallel in a multithreaded program, you have to call one operator exclusively. This is necessary to allow HALCON to initialize internal structures.

  In principle, you can choose any HALCON operator for this initial call; we recommend `reset_obj_db` as this operator initializes the global image size.

- **I/O**
  Under Windows NT/2000/XP, use I/O operators (including graphics operators like `open_window` or `disp_image`) *only in the main thread*, otherwise you might get a deadlock. This means that you should not open a window in one thread and request a user interaction in it from another thread. In the Reference Manual, these operators are marked as *locally reentrant* (see section 5.2.1).

  Keep in mind that operators which create or delete files work exclusively, i.e., other threads have to wait.

The programmer has to assure that threads do not access the same file (or handle) simultanously!

- **Multithreading vs. Automatic Parallelization**
  If you explicitely balance the load on multiple processors in a multithreaded program, we recommend to switch off the automatic parallelization mechanism in order to get an optimal performance. How to switch of the automatic parallelization is described in section 5.3.1.

5.3 Additional Information

This section contains additional information that helps you to use Parallel HALCON.

5.3.1 How to Switch Off Reentrancy or Automatic Parallelization

You can switch off parts of the features of Parallel HALCON with the help of the operator set_system. To switch off the automatic parallelization mechanism, call (HDevelop notation, see the Reference Manual for more information)

```
set_system('parallelize_operators','false')
```

To switch of reentrancy, call

```
set_system('reentrant','false')
```

Of course, you can switch on both behaviors again by calling set_system with the 'true' as the second parameter. Please note, that by switching off reentrancy you also switch off automatic parallelization, as it requires reentrancy.

Switch off these features only if you are sure you don't need them but want to save the corresponding computing overhead. If you write sequential programs to be run on a single-processor computer, the best way to save overhead is to use standard HALCON, of course.

A reason for switching off the automatic parallelization mechanism could be for debugging or if your multithreaded program does its own scheduling and does not want Parallel HALCON to interfere via automatic parallelization. Note, that you do not need to switch off automatic parallelization when using Parallel HALCON on a single-processor computer; Parallel HALCON does not create any corresponding overhead if it detects only one processor.

5.3.2 Using a Frame Grabber in Parallel HALCON

All frame grabbers supported by HALCON can be used in Parallel HALCON as well. Please note, that none of the frame grabber operators is automatically parallelized. Most of the operators are reentrant, only the operators concerned with the connection to the frame grabber (open_framegrabber, info_framegrabber, close_framegrabber, and

close_all_framegrabbers) are processed completely exclusively. Furthermore, these operators are *local*, i.e., under Windows NT/2000/XP they should be called from the main thread (see section 5.2.1).

Under Windows NT/2000/XP, each frame grabber interface comes as *two DLLs*[1], one for standard HALCON (prefix HFG) and one for Parallel HALCON (prefix parHFG). Both HALCON versions automatically load "their" interface libraries, so you do not need to worry about it.

Under UNIX, both standard HALCON and Parallel HALCON work with the same shared library (prefix HFG).

5.3.3 Extension Packages and Parallel HALCON

To be used in Parallel HALCON, extension packages must be provided in a second version including the prefix par in the name of the libraries. For example, if the package is called halconuser, Parallel HALCON looks for the libraries parhalconuser.dll under Windows NT/2000/XP or libparhalconuser.so under UNIX, respectively.

More information about extension packages in Parallel HALCON can be found in the Extension Package Programmer's Manual .

5.3.4 Parallel HALCON and HALCON Spy

As HALCON Spy (see section 6.4) is working sequentially, it cannot be used to monitor a Parallel HALCON program.

[1] see section 2.1.4 for the file structure of HALCON

Chapter 6

Tips and Tricks

This chapter contains information that helps you working with HALCON, including sections on troubleshooting.

6.1 News About HALCON

If you select HDevelop's menu entry `Help` ▷ `HALCON News (WWW)`, you can check for the latest news about HALCON on MVTec's WWW server, e.g., whether new extension packages, frame grabber interfaces, or HALCON versions are available.

6.2 A Note on Windows 2000 and Windows XP

By default, Windows 2000 and Windows XP use visual effects, e.g., when opening menus, that as a side-effect slow down programs with graphics output. In the context of HALCON, especially HDevelop is affected significantly. We therefore recommend to disable these effects in the dialog `Start` ▷ `Settings` ▷ `Control Panel` ▷ `Display`.

6.3 Online Help in HDevelop

HDevelop offers you a broad range of support.

- *System suggestions*
  Based on the *operator knowledge base*, the system offers specific advice to choose an appropriate operator. Thus, there are suggestions for reasonable *predecessors* and *successors*. If you are searching for different ways of solving an image analysis problem you may have a look at *alternatives* or *references* of an operator. If you only have some keywords or thematic aspects in mind which an operator has to fulfill, but you cannot remember the operator's name, you have the possibility to obtain an operator by specifying one or more *keywords*.

- *Online help on operators*
  HALCON offers a detailed *online help* for each HDevelop operator. These manual pages are highly structured, thus allowing you to easily get an understanding of an operator. Moreover, *cross references* immediately give you a survey of the operator's relations. To use this help you only need a standard HTML browser.

- *Debugging help*
  You may choose between different *modes of running* a program. You have the possibilities to perform single steps of a program, to set breakpoints, or to run a program continuously.

  To get meaningful *debugging support* you may also specify the environment variable `HALCONSPY` (see section 2.4.2).

- *Result visualization*
  HDevelop offers the immediate *inspection* of an operator's results. This visualization mechanism helps you to spot problems quickly. Additionally, it is very easy for you to modify graphics output parameters to optimize your graphics results.

6.4 Monitoring HALCON Programs with HALCON Spy

HALCON Spy helps you to debug image processing programs realized with HALCON operators by monitoring calls to HALCON operators and displaying their input and output data in graphical or textual form. Furthermore, it allows you to step through HALCON programs.

HALCON Spy is activated within a HALCON program by inserting the line (in HDevelop notation)

```
set_spy('mode','on')
```

Alternatively, you can activate HALCON Spy for an already linked program by defining the environment variable `%HALCONSPY%` (i.e., by setting it to any value). How to set environment variables is described in section 2.4.

You specify the monitoring mode by calling the operator `set_spy` again with a pair of parameters, for example

```
set_spy('operator','on')
set_spy('input_control','on')
```

to be informed about all operator calls and the names and values of input control parameters. The monitoring mode can also be specified via the environment variable `%HALCONSPY%`. Under Windows NT/2000/XP, set `%HALCONSPY%` to the value

```
operator=on;input_control=on
```

to get the same mode as in the example above. Under UNIX, use a *colon* instead of a semicolon to separate options.

Please take a look at the entry for `set_spy` in the HALCON Reference Manuals for detailed information on all the debugging options. Note, that HALCON Spy does not work properly under Parallel HALCON.

6.5 Troubleshooting

This section offers help for problems encountered during installing or uninstalling HALCON, when using HDevelop, or when using Parallel HALCON.

6.5.1 Problems During Installation

- **Registration of `halconx.dll` failed**
  On some systems you might get a warning message that the HALCON/COM interface library `halconx.dll` failed to self-register. A possible cause for this may be that the Microsoft library `atl.dll` was not registered properly. This library resides in the directory `%SystemRoot%\system32`, e.g., `C:\WINNT\system32`. To register the library, open a Windows Command Prompt, change into the directory `misc\i586-nt4` on the CD, and execute the supplied program `reg_halconx` twice as follows:

  ```
  reg_halconx atl.dll
  reg_halconx
  ```

  The first call of `reg_halconx` registers `atl.dll`, the second one registers `halconx.dll`.

  As an alternative to the Command Prompt, you can use the dialog `Start` ▷ `Run`; here, you must either type the full path of the program `reg_halconx` or select the program via the button `Browse`.

- **Installing and uninstalling the license manager daemon**
  Occasionally, the FLEXlm license manager daemon needed for floating licenses is not installed properly by the HALCON setup. How to install the license manager daemon manually is described in section 2.3.4.1.

6.5.2 Problems During Uninstallation

- **Unregistration of `halconx.dll`**
  If you had to register the HALCON/COM interface library `halconx.dll` manually as described in section 6.5.1, you must unregister it manually before you can uninstall HALCON. To do so, insert a HALCON CD, then open a Windows Command Prompt, change into the directory `misc\i586-nt4` on the CD, and execute the supplied program `reg_halconx` as follows:

  ```
  reg_halconx /u
  ```

  As an alternative to the Command Prompt, open the dialog `Start` ▷ `Run`, select the program `reg_halconx` via the button `Browse`, append the option `/u`, and then click `OK`.

- **Uninstallation of the license manager daemon**
  As mentioned in section 2.2.1, if you uninstall a HALCON 5.0 or 5.1 version with floating licenses the FLEXlm license manager daemon occasionally is not uninstalled properly. How to uninstall the license manager daemon manually is described in section 2.3.4.1.

- **“Internal Error”**
  If the uninstall process is terminates with a message like

  > **“Internal Error, unable to load or call external DLL. Please contact your distributor for more information.”**

  the most likely reason is that a new HALCON version was installed over an existing one without completely removing the old files first.

  Other possible reasons might be that the whole HALCON directory was moved to another position on the hard disk, or the environment variable `%HALCONROOT%` was changed manually. You have to follow the following steps to recover from the error:

  1. Check if the environment variable `%HALCONROOT%` matches the location of your HALCON directory. You can check this via the system control panel `System` (look for `Environment`) or in a Windows Command Prompt via `echo %HALCONROOT%`. If the variable contains nothing or the files are in some other location, you have to set HALCONROOT manually via the `System` control panel.

  2. Check if these following files / directories are present:

     - In the directory `%HALCONROOT%\FLEXlm\i586-nt4`: `HalconUninst.dll`[1]
       Note that by default the Windows Explorer doesn’t show DLL files, unless you explicitly tell it to do so.
       `HalconUninst.dll` is a HALCON specific DLL for the uninstallation process. If this file has been removed you can get a copy of the file from the directory `FLEXlm\i586-nt4` on the HALCON CD.

     - **Only for HALCON releases $\geq$ 6.1**
       In the directory `C:\Program Files\InstallShield Installation Information` (or similar): the directory
       `{BBEC9F40-4A36-11D6-A14C-00E0296C2846}` with a set of files.
       This directory has been created during the installation. If it has been removed, an automatic uninstallation is not possible.

     - **Only for HALCON releases $<$ 6.1**
       In your `%HALCONROOT%` directory: `Uninst.isu`
       This file has been created during the installation. If it has been removed, an automatic uninstallation is not possible.

  3. Check, if the registry entry for the uninstaller is set properly: Start `regedit.exe` in a Windows Command Prompt or in the dialog `Start` ▷ `Run`.

     - **Only for HALCON releases $\geq$ 6.1**
       Go to

       ```
       HKEY_LOCAL_MACHINE -> SOFTWARE -> Microsoft -> Windows ->
         CurrentVersion -> Uninstall ->
         {BBEC9F40-4A36-11D6-A14C-00E0296C2846}
       ```

       There, you should find a key named `UninstallString`. The value of this string should be something like this (the option `-c...` is only included if you

[1] For HALCON 5.0 and 5.1, this DLL was called `CSUninst.dll`.

have chosen an installation with floating licenses):

```
RunDll32 C:\PROGRA~1\COMMON~1\INSTAL~1\engine\6\INTEL3~1\
Ctor.dll,
LaunchSetup "C:\Program Files\InstallShield Installation
Information\{BBEC9F40-4A36-11D6-A14C-00E0296C2846}\
setup.exe" -l0x9 UninstallHALCON
```

Make sure that the path `C:\Program Files\MVTec\HALCON` (or equivalent) in the above example points to the `%HALCONROOT%` directory. **Note that filenames that contain blanks have to be quoted with** `"path"`. This is true in the above example since "Program Files" does contain a blank. Older versions of the HALCON setup program failed to do so. If you encounter unquoted path names containing blanks, please insert the quotation marks yourself.

- **Only for HALCON releases $<$ 6.1**
  Go to

  ```
  HKEY_LOCAL_MACHINE -> SOFTWARE -> Microsoft -> Windows ->
    CurrentVersion -> Uninstall -> HALCON <Version-Number>
  ```

  with `<Version-Number>` being the version number of the HALCON version you want to uninstall or is not present. There, you should find a key named `UninstallString`. The value of this string should be something like this (the option `-c...` is only included if you have chosen an installation with floating licenses):

  ```
  C:\WINNT\IsUninst.exe
  -f"C:\Program Files\MVTec\HALCON\Uninst.isu"
  -c"C:\Program Files\MVTec\HALCON\FLEXlm\i586-nt4\
  HalconUninst.dll"
  ```

  Make sure that the path `C:\Program Files\MVTec\HALCON` (or equivalent) in the above example points to the `%HALCONROOT%` directory. **Note that filenames that contain blanks have to be quoted with** `"path"`. This is true in the above example since "Program Files" does contain a blank. Older versions of the HALCON setup program failed to do so. If you encounter unquoted path names containing blanks, please insert the quotation marks yourself.

4. Close the registry editor and try to run the uninstaller again.

- **Uninstallation failed**
  If the automatic uninstallation fails for another reason, proceed as follows:
  - For floating licenses only: Uninstall the license manager daemon as described in section 2.3.4.1.
  - Start `regedit` and delete the key

    ```
    HKEY_LOCAL_MACHINE -> SOFTWARE -> MVTec -> HALCON
    ```

- **Only for HALCON releases $\geq$ 6.1**
  Also delete the key

```
HKEY_LOCAL_MACHINE -> SOFTWARE -> Microsoft -> Windows ->
  CurrentVersion -> Uninstall ->
  {BBEC9F40-4A36-11D6-A14C-00E0296C2846}
```

- **Only for HALCON releases $<$ 6.1**
  Also delete the key

```
HKEY_LOCAL_MACHINE -> SOFTWARE -> Microsoft -> Windows ->
  CurrentVersion -> Uninstall -> HALCON
```

- Using, e.g., the Windows Explorer, delete the directory

```
%SystemRoot%\Profiles\All Users\Start Menu\Programs\MVTec HALCON
```

  Note that `%SystemRoot%` usually is `C:\WINNT`.

- Finally, delete the HALCON base directory `%HALCONROOT%`.

6.5.3 Problems Concerning Licenses

If you encounter problems with your HALCON license even though your license file exists and is located in the correct directory, a first step is always to check if the information identifying your computer (or dongle) (see section 2.3.1) matches the corresponding entries in the license file (see section 2.3.3). If the two do not match, please send the new identifying information to your distributor. See below if you encounter problems with extracting the identifying information.

If you are using floating licenses, please have a look at section 2.3.4, especially regarding the choice of a suitable port number for the license manager daemon.

If you are using a dongle-bound license with HALCON 6.0.2 or higher and get the message "license not found" or a similar error message, you might need to uninstall the old dongle driver and install the new one manually as described in section 2.3.5.1.

6.5.3.1 Problems When Extracting Identifying Information

- **"About HDevelop" does not show any host IDs**
  If HDevelop fails to detect any host IDs although your computer does have a network board, a Pentium III, or a dongle, please try to extract the host IDs manually as described in section 2.3.1.2.

- **Licensing via network card does not work when network is not connected**
  On Windows 2000 and Windows XP systems, you must disable Media Sense (DHCP) when no network is connected to the network card. Usually, it is sufficient to disable the DHCP protocol in this case. Further details can be found under `http://support.microsoft.com/support/kb/articles/Q239/9/24.asp`.

- `lmhostid -ether` **returns** `"ffffffff"` **or** `"0"`

  If `lmhostid` returns `"ffffffff"` or `"0"`, this usually indicates that you do not have a network board. If you do have one, on Windows 2000 and Windows XP systems check whether the client for Microsoft networks is installed in the dialog `Start` ▷ `Settings` ▷ `Network and Dial-up Connections` ▷ `Local Area Connections` ▷ `Properties`. If the client for Microsoft networks does not appear in the list install it by clicking `Install` and then selecting it from the list of clients. Then, repeat the steps described in sections 2.3.1.1 or 2.3.1.2.

  On Windows NT systems check whether the NetBEUI and TCP/IP protocols are installed in the dialog `Start` ▷ `Settings` ▷ `Control Panel` ▷ `Network` ▷ `Protocol`. If the protocols do not appear in the dialog, please install these two protocols by adding them in the dialog. Then, repeat the steps described in sections 2.3.1.1 or 2.3.1.2.

- **Multiple IDs for only one network card**

  On Windows 2000 and Windows XP systems, sometimes more than one ID is returned even if there is only a single network card. In this case, use the ID that remains when both the NetBEUI and IPX/SPX protocols are disabled. Alternatively, use the ID that does not change when you reboot the machine.

- `lmhostid -cpu64` **returns** `""`

  If `lmhostid` returns an output like

  ```
  > lmhostid -cpu64
  lmhostid - Copyright (C) 1989-2000 Globetrotter Software, Inc.
  The FLEXlm host ID of this machine is ""
  lmhostid: FLEXlm function not available in this version <-45,520>
  ```

  this indicates that the processor of your computer does not provide a CPU ID. As described in section 2.3.1.2, the most probable reason is that the service providing the CPU ID is disabled in the computer's BIOS. You can check and enable this service in the BIOS configuration mode.

  If you cannot find a corresponding service entry in the BIOS of your computer, this means that its processor does not provide a CPU ID. Note, that currently only Pentium III processors provide this ID; the output above, e.g., stems from an AMD Athlon processor.

- `lmhostid -flexid` **does not return the dongle ID**

  If `lmhostid` does not return the ID that is printed on the back of the dongle, check whether the dongle driver is installed and configured correctly as described in section 2.3.5.

  If the driver is installed but `lmhostid` still does not return the correct ID, please check the corresponding port (parallel or USB) of your computer, before requesting a new dongle.

6.5.4 Troubleshooting in HDevelop

This section explains some typical errors while starting HDevelop and their reasons.

- **No license found**

  This error message might have several reasons:

  - The file `%HALCONROOT%\license\license.dat` is missing and/or not readable.

  - Your license is not valid on this machine.
  - In case of floating licenses: There are too many licenses active.

- **Lost connection to license server**
  Verify if the license server is running. You may also check whether your machine is properly connected with the server. For this you may need to contact your system administrator.
- **No license for this operator**
  The operator which you try to execute belongs to a HALCON module which is not licensed. Obtain a new license including this module.
- **Wrong architecture**
  This error indicates that you are using an architecture which is not compatible with your HALCON version. Check the variable ARCHITECTURE or try to install the proper HALCON version.
- **hdevelop: Command not found**
  Check your system environment variable `PATH`. It has to include the path `$HALCONROOT/bin/$ARCHITECTURE`.
- **lib* : can't open file**
  For UNIX architectures you have to check the system variable `LD_LIBRARY_PATH` (see section 2.4.2).
- **No help files for package <package-name> in directory <directory>**
  Possible reasons for this error message are:
  - No files `%HALCONROOT%\help\*` (if the package name is "system") or no help files in one of the user packages.
  - If the package name is "system": Wrong HALCONROOT
  - Check the file protection. Probably HDevelop cannot access important files.
- **Help file for package <package-name> is corrupt**
  Possible reasons for this error message are:
  - If the package name is "system": Inconsistent version of `%HALCONROOT%\help\*` or wrong HALCONROOT
  - If the package name is that of a user package: Inconsistent version of the help files of this package.
- **Can't open display**
  If you see an error message like this you may have a wrong system variable `DISPLAY` and/or your program is not allowed to open a window by the specified X-server.

6.5.5 Troubleshooting for Parallel HALCON

- **Parallel HALCON does not achieve any speedup**
  If Parallel HALCON does not achieve any speedup on a multi-processor hardware, maybe

you forgot to initialize Parallel HALCON as described in section 5.1.1. You must initialize Parallel HALCON once on each parallel hardware it is to be used on. With this initialization, Parallel HALCON scans the hardware and checks its potential for parallel processing.

If you already initialized Parallel HALCON, you can check whether Parallel HALCON really "found" the processors by calling the operator `get_system` with the parameter `'processor_num'` (see the corresponding entry in the Reference Manual for more information). Please note, that this operator must be called from Parallel HALCON to yield meaningful results; from standard HALCON, it returns `1` regardless of the actual number of processors.

Please remember that Parallel HALCON only works on shared-memory systems!

- **A Parallel HALCON program runs slower than expected within Visual Studio**

  Please note, that the developing environment Microsoft Visual Studio *massively* influences the scheduling on a multi-processor computer. As a consequence, programs using Parallel HALCON run slower than expected when started *within* Visual Studio. This concerns both the automatic parallelization mechanism and multithreaded programs in general.

  To get the full performance, create a corresponding executable (`.exe`-file) and start it *outside* Visual Studio.

- **An operator returns different results in HALCON and Parallel HALCON, respectively**

  This problem can occur if you called the operator with input parameters containing *tuples*. Note, that certain input parameters of HALCON operators must not receive tuple values; however, some operators will work without returning an error in such a case. You can check whether a parameter may receive tuples in the operator's description (on-line help or reference manual): Parameters that can receive tuples are marked with the suffix `'(-array)'` after their type, e.g., `'region(-array)'`.

6.5.6 Miscellaneous Problems

- **No refresh of window content on a UNIX system**

  On some UNIX systems the default behavior regarding occluded windows may be set in an inconvenient way for HALCON. The result is that if a window is temporarily occluded by another window, its content is not saved and restored anymore, i.e., windows remain "black" after uncovering. An example is the Linux distribution SuSE 7.0. The corresponding property is called "backing-store"; you can check the current setting of this property by typing (the following example corresponds to a SuSE 7.0 Linux system)

```
xdpyinfo | grep backing-store
```

  which should result in the output like

```
options:    backing-store YES, save-unders YES
```

  if the window content is saved and restored. You can change this behavior by modifying the file `Xservers` residing in the directory `/usr/lib/X11/xdm` (or similar, see your sys-

tem's documentation). Note, that you probably need root privileges to modify this file. Append the option `+bs` (i.e., "plus backing-store") to the line that starts the local X server:

```
:0 local /usr/X11R6/bin/X :0 vt07 +bs
```

Now, stop and start the X server again (by using the appropriate commands or by rebooting your computer); the command `xdpyinfo` now should yield the output shown above.

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